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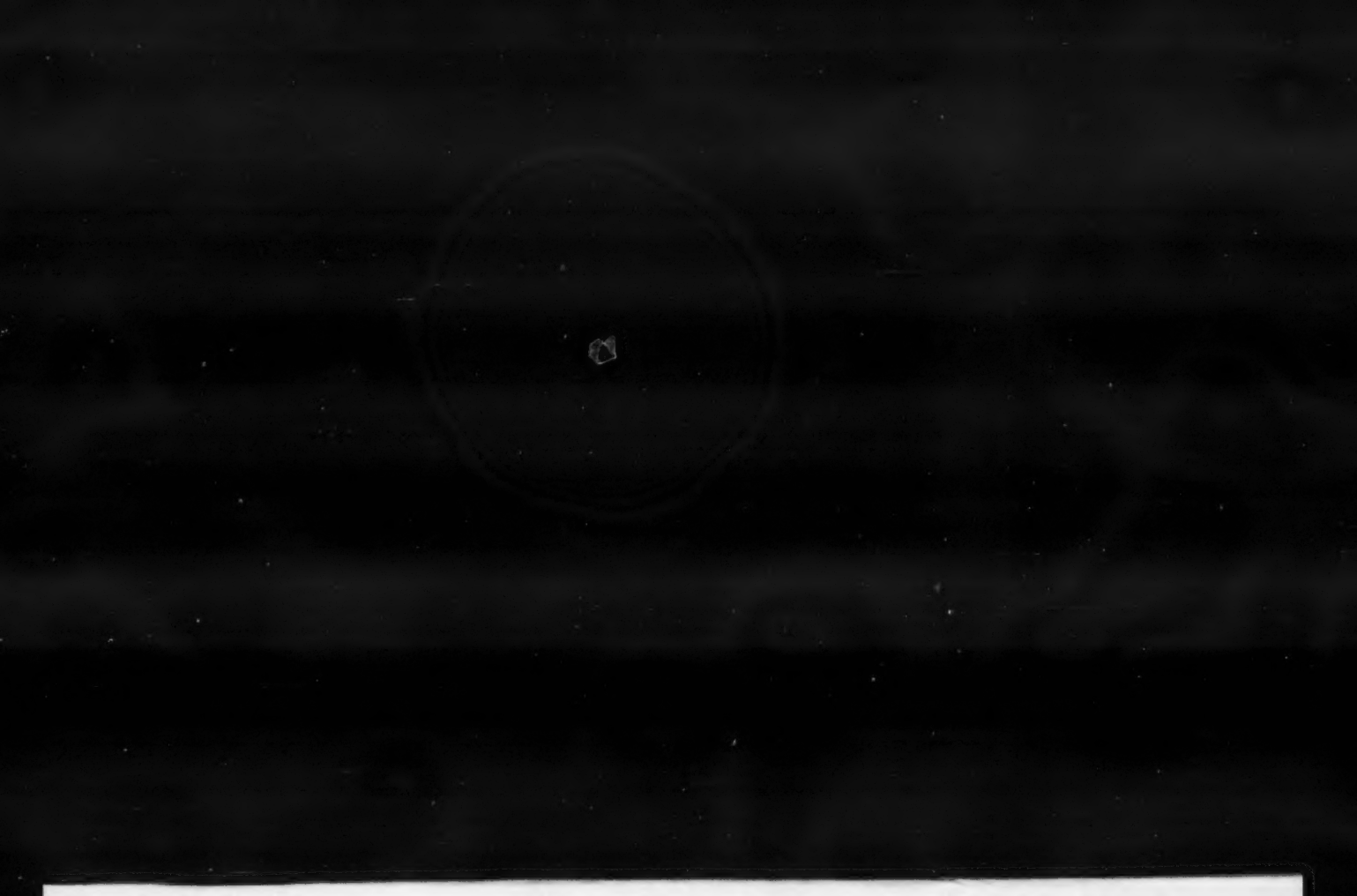

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TURBULENCE ABOVE THE OZONE LAYER*

BY ALAN E. SLATER, M.A., F.R.Met.S.

SUMMARY

It has been stated that a winged vehicle travelling through the upper atmosphere between 50 and 80 kilometres will experience turbulence due to convection currents set up by the hot ozone layer at about 50 km. The evidence for this turbulence is examined and found to be contradictory, mainly because temperature data from many rocket ascents do not show a sufficient fall-off of temperature with height to allow convection to develop.

Assuming that there is turbulence, the probable pattern of the convection currents is discussed. Uniform heating should give a regular pattern with the spacing between up-currents equal to two and a half times the thickness of the convection layer. Changes of wind with height should cause the vertical currents to be elongated in the direction of the wind shear, so that a vessel flying parallel to the shear could remain in either an up current or a down current for a considerable distance.

Finally, the probable speed of the vertical currents is discussed. Their speed would need to attain several hundred metres per second to affect noticeably a winged vessel travelling at 6 kilometres per second. Rough calculation shows that, to attain even 100 metres per second, an up current would have to rise through 30 kilometres while remaining some 10° C. hotter than the surrounding air. Such a large temperature excess appears unlikely.

Introduction

It has been stated[1] that a vehicle can support its weight in gliding at a height of 50 miles (80·6 km.) when flying at 4 miles per second (6.4 km./sec.).

It has also been stated by many writers that the region of the upper atmosphere between about 50 and 80 km. (31 and 50 miles) must be turbulent with convection currents due to the hot ozone layer at around 50 km., just as convection currents are set up in the lower atmosphere when the Earth's surface is heated by the Sun; in fact, Kellogg[2] suggests that "winged vehicles operating at these altitudes should expect to find conditions there quite 'bumpy'."

The present paper will discuss the second of these statements, because the evidence for it is conflicting. The discussion will deal with three questions:

(1) whether the rate of decrease of temperature with increasing height is sufficient to allow convectional turbulence to develop;

(2) in what pattern the air currents are likely to be distributed if such turbulence is present;

(3) whether they could attain velocities which would significantly affect a winged vehicle passing through them.

* *A paper read to a meeting of the International Astronautical Federation in Copenhagen on August 5, 1955.*

Temperature Distribution with Height

Hot air rises only so long as it is hotter than the air surrounding it at the same level; it does not necessarily do so if it is hotter than the air above it.

As air rises, the atmospheric pressure upon it is reduced, so it expands, and the expansion cools it. In the lower atmosphere, this rate of cooling is almost exactly 10° C. for every km. of rise, provided that the cooling is adiabatic—i.e. that no heat is exchanged with the environment. This proviso is embodied in the term "adiabatic lapse rate," meaning the rate at which the temperature "lapses" as the air goes up.

If the surrounding air has a lapse rate equal to, or greater than, 10° per km. (the adiabatic rate), then the up current, which started because of its warmth, will continue to be warmer than its surroundings and will go on rising. The surrounding air is then said to be "unstable."

But if the lapse rate of the surrounding air is less than 10° per km., then the up current will eventually find itself no warmer than its surroundings and will stop. In this case the air is said to be "stable."

Actually the adiabatic lapse rate at the heights we are considering is only about 9·7° C. per km.[3] owing to lessened gravity. It would be reduced further by a chemical change in the composition of the air such as the dissociation of oxygen, or the separating of gases by gravity, but neither process is noticeable below 80 km. The small proportion of ozone likewise makes no perceptible difference.

Obviously, then, the important question, whether there are convection currents at these levels or not, becomes the question whether the lapse rate of that part of the atmosphere is greater or less than the adiabatic rate of 9·7° per km.—though still with the "adiabatic" proviso that no heat passes between a convection current and its surroundings. To put it briefly, is the air above the ozone layer stable or unstable?

In Fig. 1, atmospheric temperatures between 35 and 90 km., taken from various sources, are plotted together with some representative lines showing the adiabatic lapse rate; the latter can, of course, be drawn in any part of the diagram, and the temperature of a rising mass of air follows one of these lines as it goes up. By comparing that portion of each curve which slopes upward to the left (representing a reduction of temperature with height) with an "adiabatic" line, we can see in which regions the air is shown to be stable, and in which (if any) unstable.

To take the rocket data first, the curve derived by Newell[4] from ascents in January, March and August, shows unstable air between 60 and 67 km., whereas that of the Rocket Panel,[5] which is a weighted mean derived from many sources, shows markedly stable air throughout.

In the curves calculated from meteor trail observations, Whipple[6] gives unstable air from 67 to 78 km., but a later curve by Jacchia[7] shows stable air in the same region. A curve given by Jacchia and Kopal,[8] which is a mean profile derived from direct observation, but consistent with observed atmospheric tidal oscillations, gives instability over a range from 57 to 63 km.

It is seen that there is no consistent evidence for instability, and that even where unstable regions are shown, they are comparatively shallow and are well above the hottest region, from which the presumed up currents would start.

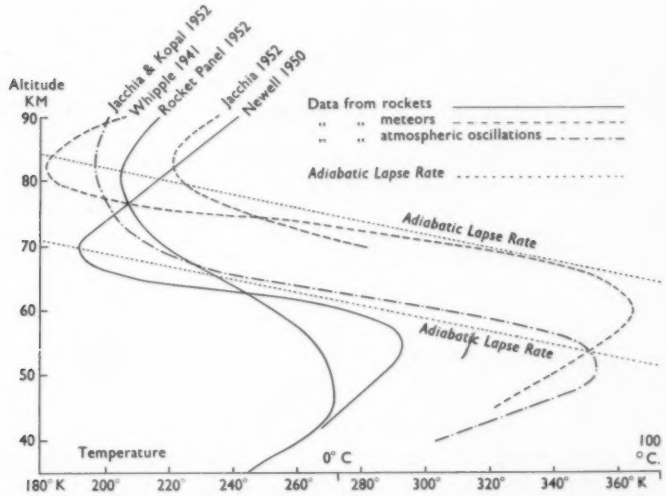

FIG. 1. Estimated upper atmosphere temperatures at levels between 35 km. and 90 km., derived from various sources; and specimen adiabatic lapse rates for comparison with actual lapse rates shown.

Let us consider some other arguments in favour of convection.

Firstly, the chemical composition of the atmosphere remains essentially the same up to 80 km., showing that there must be some mixing, otherwise there would be partial separation of the gases according to their specific weights.

Secondly, meteor trails show the presence of turbulence; but here it is necessary to distinguish between vertical motion due to convection, which produces a well-stirred atmosphere, and wave motion, in which the vertical displacement of any particular bit of air is alternately up and down, without any over-all change of height. Wave motion is only possible in stable air, and is extremely smooth, as glider pilots know, and to refer to it as "turbulence" can be misleading. For instance C. P. Olivier (quoted by Whipple)[9] finds that almost all meteor trails assume a zigzag course soon after they appear, which suggests wave motion rather than convection.

Thirdly, when temperatures at these heights are calculated by considering the radiative equilibrium,[10] it is found that the ozone layer must be so hot from absorption of ultra-violet light, and the region above it so cool from infra-red radiation by water vapour and carbon dioxide, that the region from 50 to 70 km. must necessarily be unstable, and very much so. Gowan[11] calculates that, allowing 10 per cent. water vapour and a solar temperature of 6,000° K., the temperature to give radiative equilibrium at 50 km. in the summer should be 436° K., which is far hotter than is shown by any of the curves in Fig. 1, though a solar temperature of 4,000° K. would give a temperature of 340° at 50 km., which fits well but is less likely to produce instability.

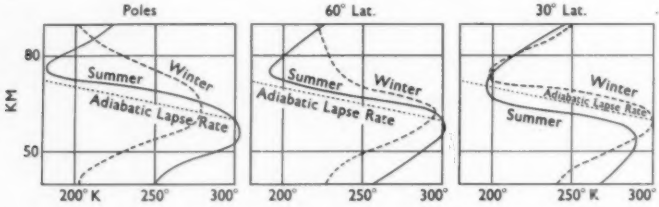

FIG. 2. Summer and Winter temperatures between 40 km. and 90 km., after W. W. Kellogg, with specimen adiabatic lapse rates inserted to show at what levels the air is unstable.

It may be objected that the curves in Fig. 1 show mean temperatures which are not based on the daily maximum of the ozone layer, which occurs shortly after mid-day. If convection took place only at limited times and places, it would still be enough to keep the air well mixed. Johnson[12] gives a daily range with a maximum value of 5·3° C. at 48 km., 2·5° at 60 km., and 1° at 70 km., over White Sands, New Mexico. This would make little difference to the stability shown by any of the curves in Fig. 1. However, Gowan[11] gives a night cooling at 50 km. of 30° C. in winter and 20° in summer.

As to seasonal variations, Kellogg[2] gives diagrams, derived from current data, showing that the air at certain heights between 60 and 75 km. should be unstable in the summer at all latitudes, while in the winter it is unstable only at latitudes between 30° and the equator (Fig. 2).

Summing up: the balance of evidence seems to be in favour of instability (lapse rate greater than adiabatic) and the consequent convection currents, but not throughout the whole thickness of the region from 50 to 80 km. There is, however, a possibility that the change of temperature in a convection current is not adiabatic; if it were to radiate heat away on its upward journey, conditions could be stable in spite of a lapse rate greater than the adiabatic; conversely, if it absorbs radiation, a lapse rate less than adiabatic could still allow convection currents.

Patterns of Convection

Convection current patterns can be broadly divided into the regular and irregular. The simplest form of regular pattern is made up of units known as Bénard cells, in each of which the fluid either goes up in the centre and comes down at the periphery, or *vice versa*. Perfect Bénard cells should be hexagonal in plan, and their horizontal diameter should be about two and a half times their vertical thickness, which is the same as the thickness of the convection layer (Fig. 3 (*a*)).

Such a pattern is easily produced artificially on a small scale, and its frequent existence in the atmosphere is shown by the pattern of such cloud types as altocumulus and stratocumulus. But, to produce it, the heating at the bottom of the layer must be uniformly distributed.

If, therefore, the air above the ozone layer is unstable all the way from 50 to 80 km., a winged vehicle travelling at 6 km./sec. would expect to hit

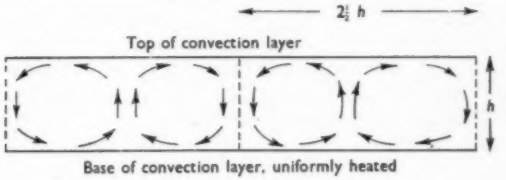

FIG. 3 (*a*) Bénard cells

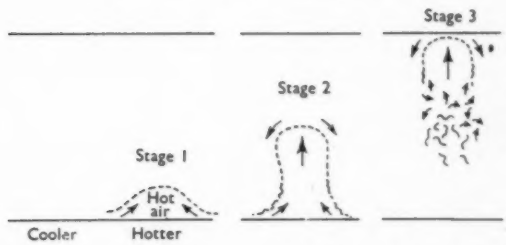

FIG. 3 (*b*) thermal "bubble."

FIG. 3. (*a*) Section through convection cells of Bénard-type, showing circulation pattern above a uniformly heated layer. (*b*) A thermal "bubble" of heated air rises from a hot patch at the base of the convection layer, which is irregularly heated.

a "bump" every 12½ seconds, but this presupposes an area of uniform ozone heating of many times the 75 km. width of a single convection cell.

However, if there is a change of wind with height, as there certainly is in this region, the cells become distorted and drawn out lengthwise in the direction of the wind shear. In the lower atmosphere this pattern is sometimes seen in the form of parallel "cloud streets," well known to glider pilots. Similar drawn-out lines of upcurrent have been seen, marked not by clouds but by the presence of soaring birds within them, by Idrac[13] in North Africa, and by Woodcock[14] off the coast of New England, U.S.A.

Examples of such wind shears are given by Kennedy, Crary and Bushnell.[15] Over Bermuda in the summer, an easterly wind blew at 58 m./sec. at 50 km. and 63 m./sec. at 55 km. Over the Canal Zone in November an E.S.E. wind blew at 52 m./sec. and 40 m./sec. respectively at the same heights, giving a shear in the opposite direction. A winged vessel flying across these "streets" would experience much more frequent "bumps" than when flying parallel to them. In the latter case it could remain in the up current, or in the intervening down current, for long enough to gain or lose a significant amount of height.

The other kind of convection pattern, the irregular, is common in the lower atmosphere, because of lack of uniformity in the heating capacity of the ground. The hot air goes up in the form of large "bubbles" of limited duration, and on the way up they mix with the surrounding air, mostly at the sides and bottom, creating small-scale turbulence in these regions (Fig. 3 (*b*)).

For this kind of turbulence, contrasts in heating at the bottom of the convection layer are needed. Although such contrasts are known to exist lower down in the ozone layer, they are much less likely at the heights we are considering, where the radiation balance is established in the ozone in a matter of

minutes or seconds,[16] whereas it takes hours or days at lower altitudes. An observation in Scotland of noctilucent clouds at about 80 km. by Paton[17] seems to suggest a sudden upsurge by a large convection "bubble" of this kind. An area of rippled cloud which he was watching (the ripples showing stability and wind shear) suddenly became chaotic at 02·18 G.M.T. as if transformed by "vigorous convection."

Speed of Vertical Currents

As Scorer says[18]: "Meteorologists cannot at present be expected to develop the mathematics of these convection currents" while their scale is unknown. At present the only sources of knowledge appear to be the motion of meteor trails and, at the top of the layer, irregularities of the base of the ionosphere and the rare noctilucent clouds.

The upward acceleration of a body of air of given excess temperature could be easily calculated if it were not for the frictional turbulence and mixing which gradually penetrate from the outside into its interior. Ignoring friction, at a temperature of 300° K. a rising body of air will accelerate upwards at 0·01 *g* if it is 3° C. hotter than its surroundings, or 0·1 *g* if it is 30° hotter. Lange[19] suggests subtracting 20 to 30 per cent. for the effects of friction on the speed of a thermal convection current in the lower atmosphere.

The effect on a winged vehicle when entering an upcurrent is to increase the lift by increasing the angle of incidence. The increase of incidence depends solely on the proportion between the speed of the upcurrent and the flying speed of the wing. For thermal currents in the lower atmosphere, a value of 2 m./sec. is common, 5 m./sec. frequent and 10 m./sec. less frequent. In thunderstorms upcurrents of 30 m./sec. have been found, with perhaps 50 m./sec. as an upper limit. It would probably take a vertical current of a few hundreds of metres per second to worry the designers of a winged vehicle intended to travel at 6 km./sec. forward speed.

Rough calculation, allowing for Lange's reduction for friction (which is extremely tentative), show that, for an upcurrent to reach a speed of 100 m./sec. after rising through 30 km., it would have to be, and remain, some 10° C. hotter than its surroundings. But whether such a temperature difference is at all probable, nobody is likely at present to venture an opinion. It is far greater than the temperature excess, of the order of 1° C., which is all that is needed in the lower atmosphere to start a thermal current rising.

To summarize, therefore: there is some doubt whether the region from 50 to 80 km. is turbulent; and, if it is, there is further doubt whether the vertical currents are strong enough to affect significantly the passage of a winged vehicle through them.

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AN ANALOGUE COMPUTER FOR THE VERTICAL ROCKET LANDING AND TAKE OFF PROBLEMS

By C. A. Cross, M.A.

SUMMARY

An hydraulic analogue has been constructed for the problem of a rocket moving vertically in a uniform gravitational field. The constants of the analogue have been arranged to represent a rocket of mass 128 tons, mass ratio 4·3. and exhaust velocity 1·15 miles per second during the last 400 miles of its fall from infinity on to the surface of the Moon.

Results from the analogue have been shown to agree well with the exact solutions that can be obtained in the restricted cases where the differential equations can be integrated.

Fitted with a manual control of the rocket motor throttle, the analogue has been used to test the ability of a number of individuals to perform a vertical rocket landing on the Moon, and their response to a programme of simple training.

Introduction

In an informal discussion after a meeting of the Midlands Branch on December 11, 1954, the author suggested that it might be quite easy to construct a "Link-trainer" type of apparatus to simulate the problem of making a vertical landing on the Moon's surface. This would provide a display of altitude, velocity, time, fuel stock, and rate of burning of the fuel. It would be provided with a single throttle control with which the victim (or trainee) would control the fuel rate in an attempt to make a safe landing.

In February, 1955, this idea came to fruition, and the analogue computer described in this paper was built. When it had been successfully operated some solutions of the differential equations were computed in order to check the accuracy of the analogue. These solutions have not been reported in the literature, so they are presented in this paper together with an account of the details of the analogue computer and the trials that have been carried out with it.

Mathematical

The differential equations for the vertical motion of a rocket in a uniform gravitational field are well known.[1]

$$\frac{dV}{dt} = g + U/M\frac{dm}{dt} \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where V is the velocity of the rocket, g the strength of the field, M the mass of the rocket, and U the exhaust velocity.

Equation (1) can be integrated to give the velocity of the rocket at any given moment without making any assumptions about the manner in which the fuel has been burnt:

$$V = gt + C - U\log_e\frac{M}{M_t} \quad .. \quad .. \quad .. \quad (2)$$

Where C is the velocity of the rocket at an arbitrarily chosen zero time, and M–M_t is the mass of fuel burnt at time t. The velocity depends only upon this mass, and not upon the manner in which it has been burnt. Equation (2) cannot however be integrated again to obtain the position of the rocket unless the relationship between M_t and t is defined. Integrations have been reported for the case where the rate of burning is controlled to give a constant acceleration.[1,2] A solution for the case when the fuel is burnt at a constant rate K does not seem to be available.

Fixing the start up of the motor as the zero time this condition gives $M_t = M - kt$. Making this substitution equation (2) may be integrated to give:

$$x = \tfrac{1}{2}gt^2 + ct - ut + U\left(\frac{M}{K} - t\right)\log_e\frac{M}{(M - Kt)} \quad .. \quad (3)$$

Thus Equations (2) and (3) allow us to calculate the position and velocity of a rocket falling in a uniform gravitational field whose motor is switched on when the rocket reaches a velocity C. In particular, by substituting $V = Q$, we can obtain the distance the rocket would fall before being brought to rest by the retardation of the motor, and the time this would take.

What we need to know for a successful landing is the altitude at which the motor should be switched on so as to bring the rocket to rest on the surface which it would have hit, if unretarded, with a velocity C_s. (C_s corresponds with the escape velocity).

Thus we are given:

M, the initial mass of the rocket.
U, the exhaust velocity.

K, the fuel rate.
C_s, the "escape velocity."
g, the surface gravity.

The unknowns are:

X_o, the altitude at which the motor is switched on.
C, the velocity at this altitude.
t, the duration of firing of the motor.
t_o, the time the rocket would take to reach the surface from altitude.
X_o if it fell without rocket retardation.

For a successful landing we make the condition $V = O$ when $X = X_o$. Thus from equations (2) and (3) we have:

$$U \log_e \frac{M}{M - Kt} = gt + C \quad .. \quad .. \quad .. \quad (4)$$

$$X_o + \tfrac{1}{2}gt^2 + Ct - Ut + U\left(\frac{M}{K} - t\right) \log_e \frac{M}{M - Kt} \quad .. \quad (5)$$

Whilst from first principles we have

$$C_s = C + gt_o \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6)$$

$$X_o = Ct_o + \tfrac{1}{2}gt^2_o \quad .. \quad .. \quad .. \quad .. \quad (7)$$

The solution of these four simultaneous equations provides an unique set of values for the four unknowns. With these fixed the actual course of velocity and altitude may be calculated from (2) and (3).

The numerical evaluation of the equations has been carried out for $g = 10^{-3}$ miles/sec. squared, and $C_s = 1{\cdot}43$ miles/sec., which are the gravitational field and escape velocity at the Moon's surface. A rocket of initial mass 128 tons has been chosen, with an exhaust velocity of 1·15 miles/sec. The computation has been carried out for throttle settings of 10, 20, 30, 40 and 50 tons/min., and the boundary conditions are set out in Table I. The results are reported in the familiar units of tons, miles/hour, etc., rather than in the consistent f.p.s. units.

TABLE I

SOLUTIONS OF THE EQUATIONS

Throttle setting, tons per minute ..	10	20	30	40	50
Altitude on, miles (X_o)	472	229	154	116	94
Duration of firing, seconds (t) ..	588	284	187	139	111
Fuel usage, tons (Kt)	98	94·5	93·3	92·7	92·3
Extra time, seconds ($t - t_o$)	242	116	75	54	43·5

The actual course of velocity and altitude is shown for all these throttle settings in Fig. 1.

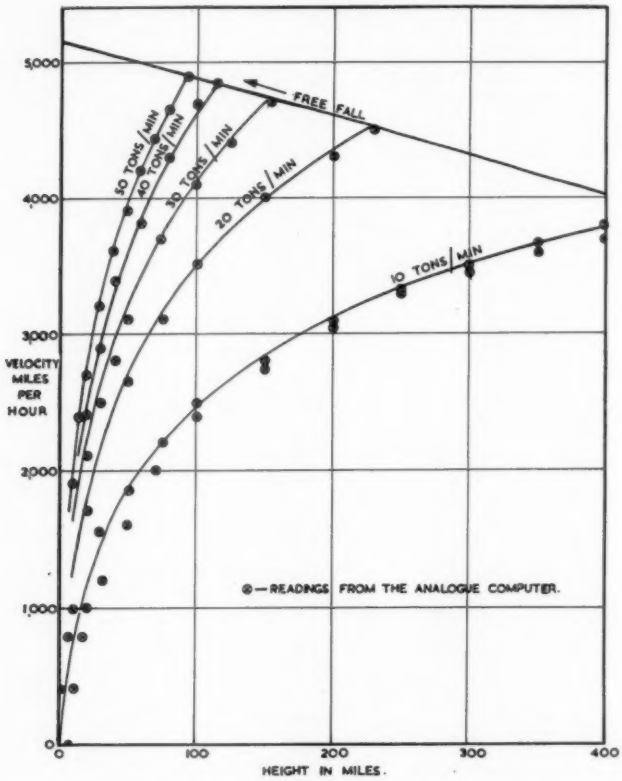

FIG. 1. Solution of equations 2 and 3.

The conditions shown in the final column of Table I evidently represent the most economical landing possible with this rocket, and they also imply no margin of safety at all, for the motor is switched on at full throttle at the last possible moment, and remains at full throttle until the actual moment of contact. During this period the thrust of the motor remains constant, but as the fuel is used up the occupants of the rocket experience a gravity increasing steadily from 1·25 g to 5·3 g at cut off.

These results also represent the limit of usefulness of this mathematical approach, for if the rate of burning fuel may be varied at will, then equation (2) cannot be integrated, and two courses are open for further advance: Either one may proceed to numerical integration for a wide range of fuel burning programmes, or one may construct an analogue computer and run off the same programmes on it.

The pros and cons of "analogue" and "digital" (or other numerical types) of computation have been extensively discussed,[3] but in this case the analogue computer offers something the other methods can never provide—the opportunity of actually making landings in control of a rocket motor as though it was falling on to the Moon.

The Analogue Computer

The principle of construction of an analogue computer is to arrange a convenient laboratory scale system whose behaviour is described by the same differential equations as the real system. When this new system is set up

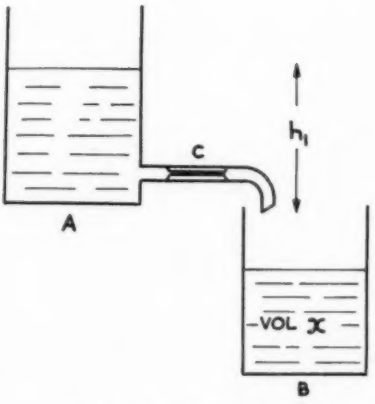

FIG. 2. Free fall analogue.

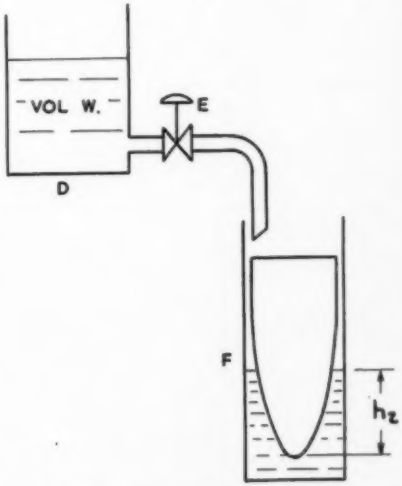

FIG. 3. Rocket motor analogue.

with appropriate constants and boundary conditions, its behaviour corresponds exactly with the real system, and may be measured with appropriately calibrated instruments.

In this work I have chosen an hydraulic analogue for two reasons. Firstly it leads to a physical system which can be measured with simple, cheap instruments (a liquid level gauge glass costs much less than a voltmeter). Secondly, because as I am a chemical engineer I find it easier to deal with fluid flow than with the flow of electrons.

Consider the simple hydraulic system of Fig. 2, in which water flows from tank A through capillary C into tank B. Now if we arrange for the level in tank A to rise steadily, then the volume collected in B is given by the equation

$$\frac{dx}{dt} = \alpha + \beta t \quad .. \quad .. \quad .. \quad .. \quad .. \quad (8)$$

where α is the initial level in A and β the rate of rise. This is formally identical with the differential equation describing the distance X fallen by a body in a uniform gravitational field. Thus we have an analogue for part of our problem, with the volume collected in tank B corresponding to the distance fallen, and the level in tank A to the velocity.

Consider now Fig. 3. Here the water in tank D may be released into tank F at any desired rate by operating the control valve E. We wish to make this system into a rocket motor analogue in which the level of water in tank F corresponds to the velocity change produced by the rocket, and the amount of water transferred to tank F to the fuel burnt. This means that if m is the initial water content of d, and m_t its content at a later time, we require:

$$\frac{m}{m_t} = e^{h_2/u} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

where h_2 is the level in tank F.

In order to achieve this relationship a special shape is needed for tank f, with a large cross sectional area at the bottom (where level $\equiv$ velocity increases only slowly for large expenditures of water $\equiv$ fuel) tapering to smaller areas at the top. This is most readily achieved by providing a cylindrical tank with a shaped insert. If r is the tank radius and Y the insert radius, the insert shape is given by

$$m\,(1 - e^{-h_2/u}) = \int_o^{h_2} \pi\,(r^2 - Y^2)\,dh_2$$

which gives on integration

$$Y^2 = r^2 - \frac{m}{\pi c}\,e^{-h_2/u} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

The insert required is the solid of revolution of equation 10 about the h axis.

We now have two simple hydraulic systems, and to obtain the complete analogue these must be combined so that the pressure of liquid in tank A, corresponding to the velocity produced by gravity, acts against the pressure in tank F, corresponding to the velocity due to the rocket motor. The way in which this is done is shown in Fig. 4. Thus the flow through capillary C in this arrangement is proportional to the hydraulic head h_1–h_2

i.e. $$\frac{dx}{dt} \propto h_1 - h_2$$

or $$\frac{dx}{dt} = \alpha + \beta t - U \log_e \frac{m}{m_t} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

Equation 11 is formally identical with equation 2, so that the behaviour of the hydraulic system of Fig. 4 is described by the same equations as for a rocket falling in a uniform gravitational field, and it forms an accurate analogue.

The analogue as finally constructed is shown in the photographs of Fig. 5 (back and front views). The components shown in the back view are identified by the same letters used in the schematic of Fig. 4. As well as the components

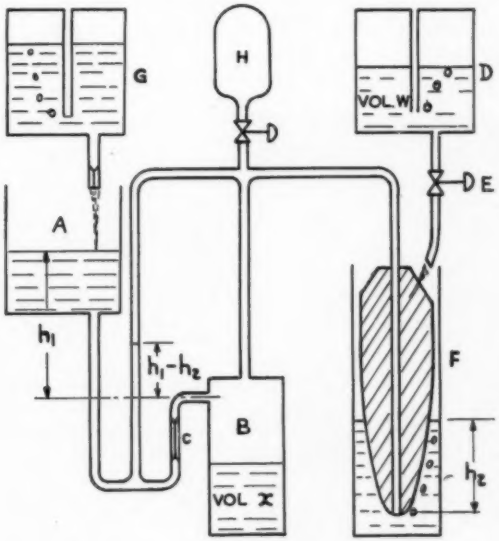

FIG. 4. The complete analogue (schematic).

already described the analogue contains a head tank G, of capacity 4 litres, from which a steady stream of water is fed to tank A at 250 ml./min. The level in tank A thus rises at a steady 0·8 cm./min., and this rise is displayed on the front dial as a time by means of a simple float and pulley system. All the other variables (including the volume of water in the range tank B) are measured by level gauge tubes carried through holes on the front panel. These tubes are clearly visible in the front view. The analogue is more complicated than the schematic diagram because of a system of return lines and an air vent tank F. These allow the water to be pumped back at the end of each run. A small compressed air reservoir (H) is also needed to supply the air that bubbles out in tank *F*.

The velocity scale reads from 5,100 miles/hr. (escape or impact velocity for a body falling from infinity) to −300 miles/hr. (to cover the case when an error of judgment starts the rocket moving upwards). For velocities below 1,000 miles/hr. the sensitivity of the scale has been increased by a factor of five by sloping the gauge glass. This gives adequate sensitivity for the actual moment of landing. For the same reason the range scale, from zero to 400 miles, has the section from zero to 50 miles spread out to occupy half the total scale length. This has been achieved by making the top half of the range vessel B very narrow (rear view, Fig. 5) so that in this section a small volume of water causes a large change in level.

The "fuel tank" D contains 500 ml. of water, calibrated 0–100 tons. With the control valve wide open this water discharges into *f* at 250 ml. (or 50 tons)/

min. When all the water is in tank F its level corresponds to 6,000 miles/hr., the all burnt velocity of the rocket in the absence of a gravitational field. As the free fall impact velocity is 5,100 miles/hr., and the acceleration due to

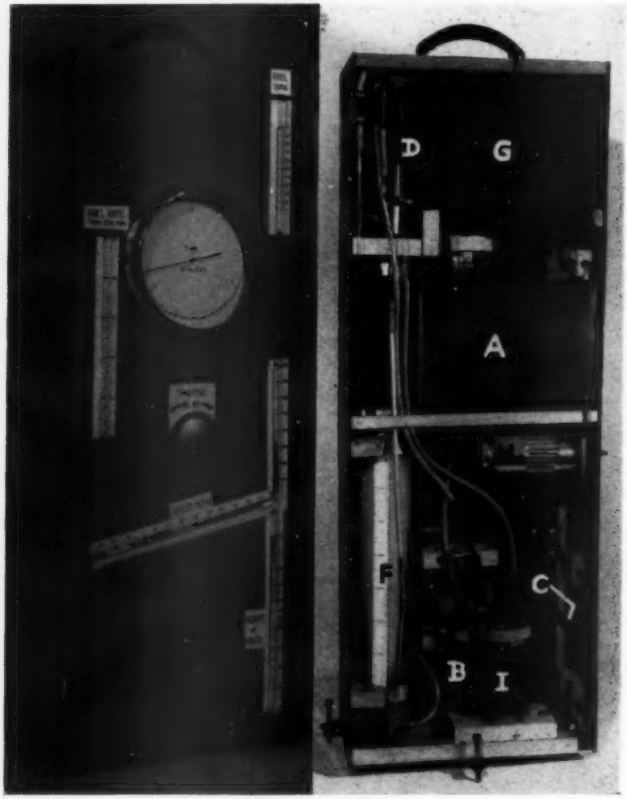

FIG. 5. The Analogue Computer (front and back views).

the Moon is 216 miles/hr/min., the rocket pilot must not take longer than $\frac{6{,}000 - 5{,}100}{216} = 4{\cdot}15$ minutes after free fall impact time to get the rocket down. If he takes longer than this he will run out of fuel and eventually crash. Conversely, Table I shows that if the motor is switched on at full throttle 67·5 seconds before free fall impact time, at an altitude of 94 miles, the rocket will land safely 111 seconds later with a fuel reserve of 5·7 tons.

Practical Experience with the Analogue

Very little trouble was experienced in bringing the analogue into successful operation. Two minor difficulties were the porosity of the wooden insert first used in tank F, which allowed the air to leak away through the wood instead of bubbling out at the bottom, and a restriction in the valve block, which made the job of pumping the water back after each run both tedious and fatiguing.

TABLE II

LANDING RUNS. (PILOT—C. A. CROSS)

Run No.	Altitude on (miles) X_o	Extra time (seconds) $t-t_o$	Duration of thrust, (seconds) t	Impact velocity (m.p.h.)	Fuel reserve (tons)	Fuel reserve corrected to zero velocity	Throttle setting (tons/min.)
1	130	230	—	95	0·5	−0·5	variable
2	120	164	—	0	2·0	2·0	"
3	100	100	—	0	4·5	4·5	"
4	100	11	—	90	8·0	7·1	"
5	110	15	—	480	9·0	4·2	"
6	120	96	—	50	3·0	2·5	"
7	120	71	—	750	10·0	2·5	"
8	115	115	—	20	2·0	1·8	"
9	115	147	—	40	3·0	2·6	"
10	115	155	—	10	3·0	2·9	"
11	93	—	102	60	6·0	5·4	50
12	116	—	140	0	5·0	5·0	40
13	154	—	175	200	8·0	6·0	30
14	229	—	282	1 mile	4·0	4·0	20
15	472	—	558	400	5·0	1·0	10
16	472	—	580	6 miles	1·0	1·0	10
17	100	52	—	40	6·0	5·6	variable
18	100	116	—	30	4·0	3·7	"
19	95	71	—	0	5·0	5·0	"
20	100	53	—	60	6·0	5·4	"
21	100	41	—	20	7·0	6·8	"
22	100	59	—	0	6·0	6·0	"
23	100	80	—	50	6·0	5·5	"
24	100	120	—	60	4·5	3·9	"
25	100	77	—	10	6·0	5·9	"
26	100	91	—	30	5·5	5·2	"

(In runs 14 and 16 the rocket was brought to rest above the surface, and this altitude is given in place of the impact velocity).

When the wooden insert had been changed to a plastic one, and the bore of the valve block suitably enlarged, these difficulties disappeared.

Calibration of the analogue proved to be a simple matter which will not be detailed here. Calibration gave me so much experience in handling the analogue that the first landing runs presented little difficulty. The results of these runs are shown in Table II. The first ten of these runs are the result of "cut and try" methods, using the analogue without any graphical aids. (At this time I had not carried out the integration reported in the mathematical section). There were two serious crashes (runs 5 and 7) due to errors of judgment, and the average fuel reserve corrected to zero impact velocity was only

2·9 tons. It may be noted that the fuel reserve figures are not entirely consistent. This is because of the limited accuracy of the fuel gauge. Motorists will realize that this difficulty may well crop up with real fuel tanks.

After the computation of Fig. 1, runs 11 to 16 on the analgoue were carried out by turning on the motor at the altitude indicated for each throttle setting in Table I, and then leaving the fuel rate fixed. Simultaneous readings of altitude and velocity were recorded as often as possible. The experimental points obtained in this way show an excellent fit with the calculated curves of Fig. 1, but in these runs it proved quite impossible to make safe landings. Even if there were no errors (see duplicate runs 15 and 16) and the rocket followed exactly the theoretical curve, the rocket motor could not be switched off at exactly the correct moment, so that invariably the rocket crashed or was left hurtling upwards again at a few hundred miles per hour. As explained earlier, the runs at constant throttle leave no margin of safety for the correction of errors.

At this stage an improved landing technique was worked out. By switching on the motor at 50 tons/min. and 100 miles altitude the rocket would be brought to rest at about five miles altitude. When the velocity has been reduced to 1,000 miles/hr. the motor is turned right down to only 5 tons/min., and it is then quite easy to bring the rocket in safely taking only about a minute more than the minimum time. Runs 17 to 22 show the improvement possible by this method. (Mean fuel reserve 5·3 tons).

Up to date eight people have been trained with the analogue, and all of them were able to make safe landings after four to six trial runs. In most cases a person faced with a "solo" landing tended to slow the rocket down too soon, often running out of fuel before the surface was reached. Two people however failed entirely to appreciate the time scale, and switched on the motor too late, crashing at high velocity with a good deal of fuel still in their tanks. The details of all these training runs are not given here, but they do show that, contrary to the often expressed view, a human being could be taught to "drive" a rocket just as he drives a car.

The present analogue represents a simplification of the real problem in two respects. Firstly, a uniform gravitational field is assumed. Thus the analogue shows increasing difference from the real inverse square law system at high altitude. It is perhaps surprising that at 400 miles the altitude and velocity errors are both less than 10 per cent., although the acceleration due to gravity is of course constant in the analogue, and at this altitude is little more than half the surface value in the real case. These differences do not vitiate the use of the analogue for landings, where the interest lies in events below 100 miles altitude, and the error is negligible. Unfortunately no simple inverse square law attachment can be built into the machine. Secondly, the analogue deals only with vertical motion. I do not believe that the control of a rocket moving freely in three dimensions would be beyond the abilities of a properly trained pilot presented with the right data, but I know that the provision of an analogue to simulate this problem is quite beyond my abilities and resources. It is not, however, beyond the resources of present day mathematics and engineering, and I feel sure that rocket crews of the future

will learn manual control of their rocket motors on this kind of "box of tricks." To obtain complete realism the controls of the rocket trainer could be installed in the cabin of a human centrifuge. The speed of the centrifuge would then be set by the analogue so that the pilot was subject to the appropriate "g." In the simple apparatus described here it is unfortunately not easy to obtain a reading corresponding to the acceleration, but as we have seen the maximum acceleration possible with the rocket chosen is 5·3 g. This would not be intolerable for the short time involved.

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FARMING ON THE MOON

The Possibility of Utilizing Soilless Cultures to Produce Crops under Lunar Conditions.

By J. W. E. H. Sholto Douglas, B.Sc., Dip. Agric., Cert. Hortic (Reading), R.H.S., R.S.A. (Econ.), F.R.H.S.

Summary

As the time for the establishment of human colonies on the Moon draws nearer, the problems of how to provide future settlers with an adequate and permanent local supply of fresh food naturally assume greater prominence. In this article the writer endeavours to discuss the possibilities of growing crops under lunar conditions, and makes some suggestions regarding apparatus and equipment. The absence of soil on the Moon, and the impracticability of transporting bulky loads by space ship from the Earth, would leave settlers with no alternative but to adopt hydroponics on a large scale. The lower lunar gravity and the perfect growing conditions that would exist inside the hydroponic apparatus, might well make it possible to produce giant plants giving yields far greater than are known on Earth.

Introduction

One of the first problems to confront a potential lunar colony is the provision of an adequate supply of food. Without assurance of sufficient nutriment to sustain at least minimum standards of health and vigour, exploration of unknown territories is impossible. The pages of history are in fact filled with pitiful and calamitous accounts of the fate that has so frequently overtaken brave and intrepid voyagers who, after the exhaustion of their resources and stores, have at length succumbed to the pangs of hunger.

Many of these disasters could, however, have been avoided had the expeditions in question possessed the technical equipment for food production that we have to-day. It is now practicable for scientists on Earth to cultivate vegetable and cereal crops in practically any area on Earth, independently of the soil or local conditions, in a very short space of time.

Hydroponics

During the past two decades very successful results in plant growing have been achieved by means of soilless cultivation in areas where ordinary methods of farming or gardening are impracticable. This system of crop production is generally known as hydroponics, a word derived from Greek and translatable as "water-working." By using hydroponics, plants may be raised in the absence of organic matter by feeding them on solutions of chemicals containing all the elements essential to healthy development and fruiting. Apart from enabling crops to be grown in places where conventional farming is impossible, soilless culture also gives very much larger yields, combined with quicker growth and lower space requirements, since the provision of adequate nutriment is guaranteed and the method provides complete control over the plants. These important advantages would become factors of considerable significance under lunar conditions.

The Green Plant

In order to appreciate fully the problems to be faced in establishing farms and gardens on the Moon, it is useful to recall briefly the essentials of plant growth, at least as we know them on Earth. The study of plant nutrition is a vast and complex subject, and it is not possible here to give more than an outline of certain salient points and the fundamentals of crop physiology. Growth is the natural result of certain chemical changes which take place regularly in all vital organisms. This gradual building up of living matter requires suitable surroundings and adequate nutrition and in the case of the green plant these essentials consist of water, air, light, mineral salts, and a support for the roots.

As green plants, unlike animals, cannot ingest solid or organic food material owing to the presence of the cell-wall, they are obliged to absorb part of their nourishment from the air, and part from solutions of inorganic salts or chemicals. These simple substances are built up by the various departments of the plants into living protoplasm through the expenditure of energy. How this energy is obtained is a subject of fascinating interest, for while the bulk of an animal's food, consisting as it does of fats, proteins and carbohydrates, contains a large store of potential energy, the simple inorganic diet of a plant is virtually devoid of any such efficiency. The answer, is of course, that plants possess the ability to build up sugars and other carbohydrates from compounds such as water and carbon dioxide, using light as the source of energy. This process is known as carbon assimilation or photosynthesis, and can only be carried on when light acts upon chlorophyll in the presence of water. Chlorophyll, which is the green colouring matter in plants, enables the Sun's radiant energy to bring about such an amazing transformation. A special relationship exists between plants and animals, called the "carbon cycle." A plant absorbs carbon dioxide from the air through stomata situated on the underside of the leaves, while, as a by-product of photosynthesis, oxygen is liberated. Animals on the other hand, breathe in oxygen and exhale carbon dioxide. Plants do, however, need some oxygen since it forms the basis of important processes which form a part of normal growth. In addition to air, light and water, certain mineral salts are required for the production of chlorophyll, and the

other functions preceding and following photosynthesis. These elements in conjunction with water are absorbed by the root hairs, utilizing the force of osmosis, while the roots themselves are supported in nature by the firmness of the soil in which they rest.

Essentials for Growth

The first of the five essentials for healthy plant growth to be considered in greater detail is water. Chemically, pure water is a compound consisting of two parts of hydrogen to one of oxygen, but in actual practice it often contains traces of other elements. In many fruits water constitutes 90 per cent. of the total weight, in green foliage leaves it is often as high as 80 per cent., while even in "dry" seeds 10 to 12 per cent. may frequently be found. In fact, germination cannot take place in the absence of sufficient moisture. Another phenomenon for which plants need ample water is transpiration, e.g., the cells in a leaf give up water in the form of vapour to the atmosphere when exposed to dry air. Unless this water is replaced the cells will lose their turgidity and the leaf wilts. Of the elements necesssary to plant life, all but carbon and to a lesser extent oxygen are derived from the water containing dissolved mineral substances or chemicals which is being continually absorbed by the roots. Even an appreciable amount of oxygen is obtained from this source. Osmosis, already mentioned, is vital to plant life, since it is by this means that water containing chemical nutrients is taken in by the root hairs and circulated through the plant, where its presence is essential for the complicated and intricate process of carbon assimilation or photosynthesis.

Sunshine consists of many different kinds of light rays, but experiments have shown that the green leaf synthesizes carbohydrates most actively in blue and red light. The importance of illumination is that it supplies the energy necessary for the conversion of carbon dioxide into organic compounds, while chlorophyll provides the mechanism by means of which this light energy is made available for the process. The rate of photosynthesis is affected by such factors as the intensity of illumination and the supply of carbon dioxide. Poor light results in little activity, while brilliant sunshine generally means rapid reaction.

Green plants derive the greater part of their food requirement from the air, and over 40 per cent. of their dry matter is accounted for by carbon obtained from the carbon dioxide in the atmosphere. This gas, together with oxygen, diffuses through the stomata into the foliage, where it is built up, as we already know, into sugars and other carbohydrates for the nourishment of the growing plant. An important process for which air is essential is respiration, or the taking in of oxygen. Here again the gas enters the plant through the stomata, diffuses throughout the spaces between each cell and finally passes into solution. Together with the oxygen derived from the water absorbed by the roots, it meets the plants' requirements of this element. Respiration itself is an interesting function, being the exact reverse of photosynthesis.

The following equations may be used to express these processes:—

Photosynthesis $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

Respiration. $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$.

It will of course be appreciated that neither process is quite so simple as these equations represent.

Chemical analysis of plant material has revealed that about forty different mineral elements are concerned with the processes of growth and nutrition, but out of these only fourteen are of vital concern. The absorption of carbon, hydrogen and oxygen has already been discussed, and the point made that all the other elements found present have been taken up in solution by the roots. These chemicals may be divided into two classes, namely the major elements and the trace elements. The former are required in relatively abundant proportions, while the latter are needed in very minute quantities only.

Nitrogen is extremely important for the production of proteins in plants. It promotes leaf and stem growth, makes for good foliage and healthy appearance, being in fact the foundation upon which the life substance, or protoplasm, is built up.

Phosphorus stimulates the production of flowers and fruits, encourages healthy root growth, expedites the process of ripening and generally results in improved quality.

Potassium plays a vital part in the synthesis of sugars and starch within the plant. It hardens and strengthens the tissues and framework while generally improving fructification.

Calcium seems to stimulate root growth and to strengthen the cell walls.

Magnesium enters into chlorophyll formation, and it may act as a transporting agent for phosphorus.

Sulphur is an important plant food, it is associated with phosphorus and is believed to assist the production of proteins.

Iron is essential for chlorophyll formation, and plays an important rôle in biological processes.

Manganese has certain rather complicated functions connected with nitrogen assimilation and reproduction. It is also said to improve the keeping quality of fruits and vegetables.

Boron has been known to stimulate the cell to abnormal growth and division.

Zinc is one of the elements essential to plant growth, but its exact rôle is still undefined.

Copper is believed to take part in chlorophyll formation.

In addition to these elements, several others can be mentioned briefly as a matter of interest. *Silicon* is considered to strengthen plant tissues; *chlorine* has been found to increase the water content of crops; *sodium* can perform certain of the functions of potassium and sometimes acts as an antidote against toxic salts; while *iodine* as is well known, prevents the disease of goitre in human beings if present in the vegetables eaten by them.

The last essential for healthy plant growth is a suitable support for the roots. To stress such an obvious requirement may, at first glance, seem unnecessary, but unless the two-fold function of the roots can be satisfactorily executed proper development will be impossible. Under natural conditions, plants derive both food and support from the Earth, but as hydroponicists have pointed out, soil is in no way a perfect medium. Erosion, drought and flood are big drawbacks, while it also harbours weeds, pests and germs. Roots

require a firm support, plenty of moisture without excess saturation, and plenty of aeration. Roots need to breathe just as much as leaves do. It is particularly important that their crowns should get plenty of oxygen from the air. For these reasons any good support for the roots, whether in soil or in soilless culture, is not only porous but capable of retaining moisture for a reasonable period. It also provides a firm basis for the growth and development of the plant from the young seedling stage right up to maturity.

Fungi and Algae

Before leaving the topic of plant nutrition, it is important to mention a few facts about one or two other classes of plants, which differ slightly from the green plant in mode of life. Some plants have no chlorophyll, for example the *Fungi* (moulds and toadstools), which includes the common mushroom (*Agaricus campestris* L. = *Psalliota campestris* Fr.). Such crops are incapable of synthesizing organic substances from simple inorganic compounds. They may obtain their food materials either from living organisms or from dead organic substances. In the former case, they are parasites, obtaining nutriment from the living cells of the host, but when they sustain themselves on dead organic matter, they are termed saprophytes. The saprophytes decompose organic bodies, breaking them down into simple compounds. The fungi differ fundamentally from normal green plants in their mode of nutrition. Since they do not possess any chlorophyll they are unable to synthesize carbohydrates from CO_2 and water. They derive their organic food material from complex carbon compounds which they obtain from external sources, and are able to absorb only soluble compounds. The hyphae secrete enzymes which convert insoluble substances to soluble ones, which are then absorbed. Although fungi are unable to make effective use of carbon dioxide, they can synthesize from soluble sugars the more complex carbohydrates which go to form their cell-walls. Similarly, if supplied with carbohydrates and relatively simple nitrogenous compounds such as ammonium salts, they are able to synthesize proteins and eventually protoplasm. Ammonium salts do not, however, represent the only possible source of nitrogen. Many complex but soluble organic nitrogenous compounds can also be absorbed and utilized.

In addition to the fungi, a word or two about the algae would be appropriate. The algae are a multifarious group, but the unicellular varieties are most likely to be of interest to food producers. Trials have been undertaken in several areas to investigate the possibilities of growing algae for food. In contrast to higher green plants, these micro-organisms are unicellular, and being supported in water, have no skeleton other than the cell-wall. Consequently, a greater proportion of their material may be devoted to useful purposes. Fifty per cent. of the dry weight as protein is common, and up to 70 per cent. has been obtained. In algae cultivation, all nutrients are applied in solution, there is no waste, and complete control can be secured over the crop. Algae need regular supplies of nutrient salts, ample light, and continuous agitation of the culture solution. A good level of CO_2 increases growth and yield. The most commonly grown organism has been *Chlorella*. The algae "farm" usually consists of sets of tanks or tubes filled with water, to which nutrient salts are

periodically added. The harvest is collected daily. As a human food, algae has good fat and vitamin content, but palatability depends on preparation of the raw material.

Comparison of Terrestrial and Lunar Conditions

The foregoing short discussion has briefly summarized the essentials of plant nutrition and physiology, as we know them on Earth. Naturally, in undertaking any transplantation of terrestrial vegetation to another planet, it would be necessary in the initial stages at any rate to supply the crops in question with the same fundamental requirements, but the possibility would exist of ultimately changing the new environment, and therefore in the end producing plants capable of withstanding vastly different conditions of life. By selection and breeding over a period of several years, the cultivator would be able eventually to evolve crops capable of growing in quite extraordinary circumstances, unlike Earth conditions—but of course that is a long-term project. At the start of any scheme of extra-terrestrial colonization, crop production would necessarily be confined to creating environments similar to what the plants have been accustomed to in this world.

In comparing conditions on the Moon with those obtaining on Earth, as far as they are related to possible crop cultivation, the following items are of the greatest significance. In the first place, it may be assumed that there is no water in liquid form existing under lunar surface conditions, although there may well be frozen ice in some quantity in crevices, or underground. Secondly, the atmosphere is virtually negligible at lower levels, thus ruling out a supply of oxygen, or of carbon dioxide, in the free state, but there might be good possibilities of securing substantial amounts of these gases by release from the rocks on the Moon. Light would of course be present, and the clear skies with absence of cloud (excepting any possible ground mists) would ensure optimum sunshine. Here the question of temperature may be briefly touched on. During the lunar day, equivalent to fourteen of our Earth days, the average noon temperatures on the surface of the crust are estimated to be 216° F., and during the long night the heat essential for plant growth would be entirely absent, since the temperature then falls to −243° F. Furthermore, terrestrial vegetation is accustomed to short periods of illumination, followed by a dark phase—the Earth night—and would have to adapt itself to the different lunar conditions.

Finally, there are the other essentials of mineral salts, and a support for the roots, to consider. It is quite probable that chemical fertilizers could be produced on the Moon, for feeding to crops, since no doubt the crust of that satellite is formed of much the same basic materials as is this globe, and all essential elements should be present—free or combined. There would be no soil, as we know it, and therefore no humus, making normal agriculture impossible. For hydroponic culture, however, there would be ample supplies of rock, which could be crushed into aggregate.

Problems to be Faced

It will be at once obvious that the problems of agricultural development on the Moon are formidable, but by no means insoluble. In the absence of air,

water and suitable temperatures, certain measures would have to be taken to create these essentials. Light would be quite satisfactory, but the different length of the days and nights would call for some adjustments. One or two other factors will also repay study, notably the low gravity, less than one-sixth's of the Earth's, and the production of nutrients.

For various technical reasons, in particular the total absence of humus, and of soil bacteria, it would be impracticable to attempt to develop normal agriculture or gardening on the Moon, even under the artificial domes of the colonies. Furthermore, it is most unlikely that sufficient space would ever be available for growth in soil to be attempted. Indeed, the only possible system for lunar conditions would be hydroponics, both for the above reasons and for the obtainment of the advantages mentioned earlier. The amount of data that has been accumulated up to date has made it possible for tentative plans to be drawn up for the eventual establishment of hydroponicums on the Moon, large and efficient enough to provide ample supplies of all vegetable foodstuffs for the use of the colonists living there. Naturally, many of the conclusions reached here are still based on hypothetical assumptions, and the preparation of final details must await the factual report of the first survey ship to reach our satellite. But it is surely time that an effort was made to stimulate thought on this subject, and that practical discussion should commence on what is after all a very vital matter.

Owing to the quite dissimilar atmospheres of the Moon and the Earth, the establishment of farms growing terrestrial crops for consumption by human beings living under lunar conditions would not be possible in the open. All of our plants need air, or water, or both, and there is no evidence to lead us to suppose that the Moon is capable of retaining these in the free state at ground level. Consequently, some form of artificial contraption would be necessary to afford satisfactory protection to crops, and to conserve the supplies of water and air that would be provided for the plants. The most convenient structures would, no doubt be large domes or tubes, made of transparent material, so as to admit light. Inside such devices, the grower could create an environment giving optimum conditions for the production of bumper harvests.

The Hydroponic Technique

Hydroponic crops, under ordinary conditions, are grown in beds of aggregate, usually mixtures of sand and stones, which are periodically moistened by infusion of nutrient solutions. These troughs are kept constantly moist, and the plants are given maximum nourishment in order to encourage higher yields. The operation of the whole system can be made automatic, while the grower, by varying the formula, may produce whatever type of plant is required. Complete control over the crop is achieved. Several modifications of hydroponics exist, and one method makes it possible for the operator to use only a liquid solution without any aggregate. Under this system, the plants are suspended on trays over a tank of water and nutrients, but first-class aeration in a very dry outdoor climate is essential to its success. In practice, especially in closed devices like tubes or greenhouses, hydroponic cultures are best if run

on the aggregate method, and on the Moon this would be doubly true, since it might be considered desirable to increase the supply of carbon dioxide in an effort to raise yield, and that in itself would cut down the amount of oxygen available for the roots, thus diminishing aeration.

A Lunar Farm

Assuming therefore that aggregate culture would be superior, we may envisage as follows a food producing unit on the Moon:—

The "farm" would consist of a series of transparent tubes, made from toughened plastic material, with one side flattened so as to rest evenly on the lunar surface. This flattened side would act as the base of the hydroponicum that would be set up inside the tube. A diameter of at least 12 feet would be desirable, so as to give height for tall plants, and to allow for two troughs separated by a centre walk running down the middle of the unit. The length could be unlimited, but one end would open into a central assembly area where fertilizers, laboratories and workers' quarters would be situated. In practice, a unit might resemble a wheel, with the tubes radiating off from the central assembly and controlling point or hub. The object of having a number of separate tubes is to enable different types of crops at various stages of growth to be raised at one and the same time. In individual production sections, it would be possible to provide each class of plants with optimum growth conditions.

The troughs or beds inside the tubes would run parallel to the length of the unit. They would be fitted with side-walls 8 inches in height, and be about a yard wide, thus allowing for a central passageway of similar breadth. The space just above the top of the rear wall, where the tube bulges outwards would provide room for the irrigation pipes, heating cable and air-conditioning apparatus. Sliding screens to exclude excessive light, and electric bulbs to give illumination during the long nights would also be included in the equipment. The growing troughs themselves would be filled with crushed rock, of $\frac{3}{8}$th to $\frac{1}{4}$-inch grade, which would serve as a support for the roots of the plants, while retaining nutrients and moisture.

At regular intervals, correctly balanced mixtures of chemical fertilizers, or synthetic resins having anion and cation exchange properties, would be applied to the growing crops by even distribution over the surface of the aggregate in the beds, or else by insertion before planting. All these operations can be easily mechanized.

In the absence of insect pests, and the probable total exclusion of soil-borne terrestrial diseases, the use of fungicides or other sprays would be unnecessary. Normal staking and tieing would no doubt be required.

The operation of the hydroponic units could be made completely automatic, and the perfect growing conditions that would obtain inside the closed tubes of the farm could indeed be termed a horticulturist's paradise.

No Insurmountable Obstacles

From the above short discussion, it will be already apparent that there are no insurmountable obstacles, at any rate as far as the theoretical aspect is

concerned, blocking the way to the establishment of food producing units on the Moon. In practice, however, a few technical problems are likely to arise. These are of sufficient importance to justify brief mention.

(*a*) *Light.*

We have found that plants growing under lunar conditions would be provided with light from natural sources. The long period of daily illumination could be exhausting to terrestrial type plants, which are conditioned to short phase illumination, followed by dark periods. It would no doubt be desirable to have screens that might be drawn inside the growing units to shut out light at intervals. In the same way, to secure healthy growth and development during the lunar night, artificial lighting would be essential. Few higher plants could stand perpetual darkness for a fortnight, since during that time chlorophyll formation would be halted, and in consequence general debility followed by necrosis would ensue.

(*b*) *Heat.*

The absence of any dense atmosphere on the Moon, which has an albedo of only 7 per cent., means that most of the Sun's heat is absorbed. Actually, this merely results in a rise of temperature on the surface until the heat absorbed is balanced by re-radiation. No heat penetrates into the surface to any marked degree, although over geological periods the amount might be appreciable. The provision of tubes or domes for the protection of crops would of course enable adequate heating or cooling arrangements to be installed, and there should be little difficulty in ensuring that suitable temperatures of from 65° F. to 80° F. were maintained within the farm units. For screening the plants against excessive solar heat during the lunar day, insulation of the units would be required; while at night some warming of the domes would be called for. If root temperatures were allowed to exceed 90° F, excessive transpiration would occur, and the plants would become desiccated.

(*c*) *Air.*

Inside the hydroponic units, an atmosphere similar to the terrestrial air ocean in composition would have to be maintained. For different crops water vapour content could be varied, and these humidity adjustments might prove most valuable in controlling growth. Experiments have been undertaken in commercial greenhouses on Earth with the object of ascertaining if any increase in the supply of carbon dioxide results in better growth. No striking improvements have yet been obtained, but it has been found that plants can use more carbon dioxide at high light intensities. This in turn could have appreciable effects on development. Under lunar conditions, it might well be that the supply of the gas in the farms could be increased. No doubt it would be practicable to allow for about 2 per cent. CO_2 in the air mixture, against only the 0·03 per cent. usual on Earth. The concentration limit for carbon dioxide supply to green plants is 15 per cent. At that level, inhibiting growth effects become noticeable.

(*a*) *Gravity.*

This is another factor that might well become significant. The Moon has a low gravity force—less than one-sixth of that of the Earth. On this planet, plant shoots are negatively geotropic, and roots are positively geotropic. Growth under terrestrial conditions proceeds at certain rates, and the rise of sap and consequent ultimate size of the crop—whether it consists of trees or small annuals—depend to a considerable extent on the influence of gravitational attraction. It is reasonable to assume that under the lower gravity conditions on the Moon, green plants would be able to grow far more quickly, and possibly attain greater heights than on Earth.

Materials Available on The Moon

Mention has already been made of the possibilities of obtaining supplies of water, nutrients and aggregate for hydroponic farms on the Moon from local sources. With regard to the former, should frozen ice exist in deep crevices in the crust, its conversion into water would be relatively simple. The release of oxygen from the rocks into which it has entered into combination with various minerals, should prove quite practicable, and most of the plans for lunar colonization are based on the assumption that large quantities of both air and water would be manufactured by release from the local rocks. These formations could be crushed up for use as building materials, and for growing media. No great technical problems would require solution as far as such operations as these were concerned.

The only other point of importance awaiting elucidation would then be the provision of fertilizer chemicals. It would be quite uneconomic to convey chemicals in bulk by spaceship to the Moon, and apart from a small initial supply, the lunar hydroponicist would have to rely on local products. The essential elements needed by the green plant have already been reviewed, and it is reasonable to assume that the rocks on the Moon would be able to yield appreciable amounts of minerals quite similar to those known on Earth. The actual choice of the individual salts which act as vehicles carrying the particular elements for feeding to the plants is immaterial, provided toxic substances are avoided, and correct antagonism and balance are maintained. In practice, compounds like nitrate of soda, sulphate of ammonia, potassium sulphate or muriate and superphosphate of lime are used. Many new combined salts are to-day coming on to the market, which contain two or three nutrient elements, and considerably reduce the bulk of formulae.

The manufacture of fertilizers, and synthetic resins, for hydroponic cultivation, is to-day well advanced, and details are available in books of reference.

Apart from the cultivation of higher plants and algae on the surface of the Moon, good possibilities might exist of establishing mushroom farms in underground caverns. The soilless growing of fungi has not yet been seriously attempted on a practical scale, and several technical problems would arise, such as control of the sugar solutions, but none of these questions would be insoluble. The food value of the edible fungi is high, and they could be produced all through the lunar night at low cost in the absence of light.

Conclusion

From this necessarily brief general outline of the possibilities of establishing food producing units on the Moon, the reader will be able to form some idea of the types of farms that are envisaged. No technical details or complete descriptions of apparatus have been given, since the object of this article is simply to bring to the notice of lunar explorers and other interested parties the main problems that might arise, and how they could be overcome.

For various reasons, it is considered that hydroponics, or soilless cultivation, would be the only practicable technique suitable under lunar conditions. The production of higher plants, fungi and algae, should be quite possible, provided protective apparatus of the right design was installed, while it seems reasonable to assume that local supplies of water and nutrients, as well as air and aggregate would be available.

The hydroponic farms that will eventually be developed on the Moon would afford absolutely perfect growing conditions, and give the operator complete control over the plants. Crops of greatly superior quality could therefore be raised. Certain modifications in plant characteristics would undoubtedly take place, due to the changed environment, and might perhaps result in crops of giant size, coming to maturity in as little as two weeks.

Handicapped as we are by having not yet had any actual physical contact with the Moon, and being comparatively ignorant of what ecological conditions might eventually be produced there, the conclusions reached at present can be only tentative and theoretical. However, hydroponics on the Earth is a tested and successful system that has been profitably operated in all sorts of climatic conditions. Given certain essentials, the hydroponicist can to-day produce crops in any area, independently of the soil, and without relying on Nature's whims. There is no doubt that provided these same essentials can be artificially obtained on the Moon, crop growing there would also be possible.

Many problems would of course arise, and skill would be needed to solve them. After the establishment of hydroponic units growing plants raised from seed brought from the Earth, and the assurance of a regular supply of food from these, the next task of interest for botanists and horticulturists would be the solution of the question as to whether any lower types of vegetation do actually flourish on the Moon's surface. Various opinions have been put forward about this, some for and some against the possibility of plant life existing under lunar conditions. Only local surveys can give the final answer, but it may well be that certain lower forms of vegetation do grow on crater floors. Whether such plants would be palatable, let alone edible for human beings, is another matter.

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(7) J. Sholto Douglas, "The Possibilities of Soilless Cultivation," Impact of Science on on Society, Vol. VI, No. 1, March, 1955, pp. 30–50. United Nations Educational, Scientific and Cultural Organization.
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ROCKET ENGINE DATA SHEETS

By D. S. Carton, A.R.Ae.S.

De Havilland Super Sprite D. Spr. 4 Rocket Engine. Take-off assistance. Self-contained, jettisonable unit.

Sea Level Maximum Performance

Thrust: 4,200 Lb.
Propellant flow rate: 26·2 lb./sec.
Specific propellant consumption: 22·5 lb./hr./Lb.
Specific impulse: 160 Lb./lb./sec.
Effective exhaust velocity: 5,150 ft./sec.
Total impulse: 120,000 Lb. sec.
Time of operation: 40 sec.

Propellants.—Oxidant: hydrogen-peroxide 80/85 per cent. with water. Fuel: kerosine (D.Eng.R.D. 2482), or wide-cut gasoline (D.Eng.R.D. 2486). Effective oxidant/fuel ratio: 20 : 1.

Description

(1) *Tanks.*—Oxidant: 57 gallons capacity (775 lb.). Welded stainless-steel cylinder. Fuel: 5 gallons capacity (40 lb.), surrounding nozzle throat.

(2) *Feed.*—Nitrogen pressurization from 9 bottles at 3,000 Lb./in.^{2} through reducing valve to tanks at 475 Lb./in.^{2}

(3) *Combustion chamber.*—Operating pressure: 275 Lb./in.^{2} Diameter: 8 in. L*: 110 in. Nozzle throat: 4 in. diameter. Expansion cone, 12° half angle. Chamber of stainless steel with an inner *flame* tube of Nimonic 75. *Hot* reaction inside; *cold* reaction between flame tube and chamber wall.

(4) *Ignition.*—Two-stage thermal ignition. Peroxide flows through a silver-plated wire-gauze catalyst pack producing first stage reaction as it flows into chamber.

(5) *Injectors.*—Fuel injected into peroxide decomposition products through a centrally-placed injector with one axial and eight radial holes.

(6) *Cooling.*—Fuel tank surrounds nozzle. Flow follows spiral-pathed cooling jacket. No cooling around body of chamber.

(7) *Control.*—1. On-off switch. 2. Firing switch. Solenoid actuator and valves permit ordered nitrogen flow ensuring arrival of peroxide before fuel at starting, and fuel stoppage before peroxide at shut-down.

(8) *Weight.*—Complete unit: full, 1,400 lb.; empty, 600 lb.

(9) *Operational.*—1952. Ministry of Supply required unit of total impulse double that of early "Sprite." Also as many as possible of the parts and tooling of the early "Sprite" to be used. Unit first ran April, 1953. 1,200 firings up to July, 1955. Production started mid-1955. Unit is jettisonable, carries own parachutes, and air bags to cushion landing.

REFERENCES

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(2) "Super Sprite," *Flight*, **68**, 183–8 (Aug. 5, 1955).

Walter 109-502 Rocket Engine. Aircraft take-off assistance. Self-contained, jettisonable unit.

SEA LEVEL MAXIMUM PERFORMANCE

Thrust: 3,300 Lb.
Propellant flow rate: 18·3 lb./sec.
Specific propellant consumption: 20 lb./hr./Lb.
Specific impulse: 180 Lb./lb./sec.
Effective exhaust velocity: 5,800 ft./sec.
Total impulse: 9,000 Lb. sec.
Time of operation: 30 sec.

Propellants.—Oxidant: hydrogen peroxide 80 per cent. (with water), 486 lb. Fuels: gasoline, 37 lb., for main combustion; hydrazine hydrate, 1 lb., for starting. Catalyst: for oxidant break down, sodium or calcium permanganate, 24 lb.
Effective oxidant/fuel/catalyst ratio: 13·1:1:0·85.

DESCRIPTION

(1) *Tanks.*—Oxidant: 36 gallons capacity, welded aluminium sphere, 28 in. outside diameter. Fuel: 5 gallons, Catalyst 2·5 gallons, both welded steel.
(2) *Feed.*—Air pressurization of tanks from 5 storage bottles at 2,250 Lb./in.^{2}
(3) *Combustion chamber.*—Operating pressure: 320 Lb./in.^{2}; 6·1 in. diameter, 16 in. long. L*: 70 in. Nozzle throat: 3 in. diameter. Expansion cone 15° half angle.
(4) *Injector.*—Axial, impinging streams of fuel and oxidant together impinge on radial spray of oxidant from plain holes in short centre body.
(5) *Cooling.*—Regenerative circulation of hydrogen peroxide.
(6) *Ignition.*—About 1 lb. of hydrazine hydrate is carried with fuel and allowed to settle out at tank base. At starting it flows first and reacts spontaneously with peroxide.
(7) *Control.*—A solenoid-controlled air valve is operated by switch in cockpit. Air valves permit flow to three tanks. Hydrazine hydrate and catalyst are made to arrive first.
(8) *Weight.*—Complete unit: full, 1,060 lb.; empty, 500 lb.
(9) *Operational details.*—109–501 and 502 identical except for flow rates. Former produced 2,200 lb. thrust 42·5 secs. S.I. 170. Both units developed from *cold* 109-500 units. Were produced in quantity and used on various German aircraft up to 1945.

REFERENCE

(1) A. D. Baxter, "Aircraft Rocket Motors," *Aircr. Engng.*, **19**, 249–57 (Aug., 1947).

Wasserfall Rocket Engine. Main engine for missile. Used in the Wasserfall guided missile.

SEA LEVEL MAXIMUM PERFORMANCE

Thrust: 17,500 Lb.
Propellant flow rate: 97 lb./sec.
Specific propellant consumption: 20 lb./hr.lb.
Specific impulse: 180 Lb./lb./sec.
Effective exhaust velocity: 5,800 ft./sec.
Total impulse: 740,000 Lb. sec.
Time of operation: 42 sec.

Propellants.—Oxidant: 90 per cent. nitric acid, 10 per cent. sulphuric acid, 3,460 lb. Fuel: *optolene* (self-igniting with acid. Complex mixture of pyrocatechin, aniline, vinylethyl ether, aromatics and gasoline. Final mixture selected to give density same as used in design calculations for dynamic reasons), 800 lb. Effective oxidant/fuel ratio: 4·35 : 1.

DESCRIPTION

(1) *Tanks.*—Both tanks form part of missile structure, 32 in. diameter mild steel. Production acid tank was to have internal anti-corrosive treatment for storage full.

(2) *Feed.*—Nitrogen pressurization of tanks from one 30-in. diameter spherical container at 3,600 Lb./in.^{2} reduced to 400 Lb./in.^{2}

(3) *Combustion chamber.*—Operating pressure: 280 Lb./in.^{2}, nearly spherical, 20 in. diameter. Volume 1·84 cu. ft. L*: 75 in. Nozzle throat: 7·56 in. diameter. Expansion cone $12\frac{1}{2}°$ half angle.

(4) *Injectors.*—Shower head, 200 acid holes with 80 fuel holes interspersed.

(5) *Cooling.*—Regenerative circulation of acid mixture.

(6) *Ignition.*—No ignition system required, propellants ignite spontaneously.

(7) *Control.*—Externally supplied electrical impulse ignites a black-powder charge bursting disc on nitrogen bottle. Gas passes through reducing valve, bursts disc at tank entrances and outlets. Fuel made to arrive first. Acid delayed by having to pass through cooling duct, and also by soluble paste partly blocking injector allowing first acid spray as annular ring about mid-radius.

(8) *Weight.*—Power unit without tanks, 730 lb.

(9) *Operational details.*—Design commenced at Peenemünde in 1942. Some 40 missiles tested. Design combustion chamber pressure of 225 Lb./in.^{2} did not produce expected thrust. Flight performance loss minimized by increasing flow rate and thrust at the expense of operating time. A number of improvements were under consideration in 1945. Directional control with graphite jet deflectors coupled to aerodynamic controls. To minimize internal drag losses and the possible problem of assymetric burn-out, vanes were explosively detached after 10 sec.

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(2) K. W. Gatland: Data Sheets, *J.B.I.S.*, **14** (4), 230–1 (July-August, 1955).
(3) J. Humphries, "Problems in Rocket Development," *J.B.I.S.*, **6** (4), 109, 114–5 (March, 1947).

A-4 Rocket Engine. Main engine for missile. Used in A-4 (V-2).

SEA LEVEL MAXIMUM PERFORMANCE

Thrust: 56,000 Lb.
Propellant flow rate: 276 lb./sec.
Specific propellant consumption: 17·8 lb./hr./Lb.
Specific impulse: 203 Lb./lb./sec.
Effective exhaust velocity: 6,515 ft./sec.
Total impulse: 3,900,000 Lb. sec.
Time of operation: 69 sec. max. Normally cut off at about 60 secs.

Propellants.—Oxidant: liquid oxygen 10,800 lb. immediately after filling. Fuel: ethanol 75 per cent. (with water), 8,400 lb. Effective oxidant/fuel ratio: 1·25 : 1.

DESCRIPTION

(1) *Tanks.*—Cylindrical, with dished ends. Aluminium.

(2) *Feed.*—Centrifugal pumps driven by turbine. Separate hydrogen-peroxide (390 lb.) and sodium permanganate liquid (30 lb.) tanks. Nitrogen pressurized into a reaction chamber. Producing 4·7 lb./sec. gas at 375 Lb./in.^{2} and 385° C. Turbine produces 460 h.p. at 3,800 r.p.m.

(3) *Combustion chamber.*—Operating pressure: 220 Lb./in.^{2} Flattened spherical, 36·3 in. maximum diameter. Volume: 13·3 cu. ft. L*: 120 in. Nozzle throat 15·5 in. diameter. Expansion cone 12½° half angle. Deep-drawn mild-steel sheet.

(4) *Injectors.*—Eighteen injector cups, each with oxygen sprays from cup base and alcohol sprays from cup walls.

(5) *Cooling.*—Regenerative circulation of alcohol mixture + 4 lines of holes in nozzle before and after throat for *film* cooling.

(6) *Ignition.*—By pyrotechnic spinning inside chamber.

(7) *Starting sequence and control.*—After filling, before ignition, fuel and oxygen pumps and lines primed. Oxygen tank is pressurized by external air supply. Igniter is electrically fired, both main propellant valves are partly opened giving reduced flow to combustion chamber. If satisfactory combustion occurs the main burning is initiated by operator. Hydrogen peroxide and catalyst delivered to reaction chamber, steam drives turbo pump assembly building up thrust. External air supply dropped. Ascent, oxygen tank pressurized by gaseous oxygen obtained from heat exchanger using turbine exhaust steam. Fuel tank ram air pressurized. About 3 sec. before cut-off thrust reduced to 17,600 Lb.

(8) *Weight.*—Power unit complete, less tanks, 2,050 lb.

(9) *Operational details.*—Preliminary design commenced in 1938. First flight 1942. More than 3,000 units made. Graphite jet deflectors used, coupled to aerodynamic controls. Thrust about 70,000 Lb. at 25 miles altitude.

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(1) W. G. A. Perring: "The Mechanism of the German Rocket Bomb V-2," *Proc. Institute of Mechanical Engineers*, **154** (1), 93–98, (June, 1946.)
(2) G. P. Sutton: *Rocket Propulsion Elements*, Wiley, New York, and Chapman and Hall, London, 1949.

R.A.E.* Alpha Rocket Engine. Main engine for model aircraft. Vickers transonic vehicle.

MAXIMUM PERFORMANCE AT 35,000 FT.

Thrust: 900 Lb.	Specific impulse: 200 Lb./lb./sec.
Propellant flow rate: 4·5 lb./sec.	Effective exhaust velocity: 6,440 ft./sec.
Specific propellant consumption: 18 lb./hr.Lb.	Total impulse: 50,000 Lb.sec.
	Time of operation: 58 sec.

Propellants.—Oxidant: hydrogen-peroxide 80 per cent. (with water), 192 lb. Fuel: methanol 57 per cent. + hydrazine hydrate 30 per cent. + water 13 per cent. + catalyst (potassium cuprocyanide), 67 lb. Effective oxidant/fuel ratio: 3·3 : 1.

DESCRIPTION

(1) *Tanks.*—Three cast stainless-steel. Peroxide, two spherical, total 14·1 gallons. Fuel tank faired to nose, 7·5 gallons.

(2) *Feed.*—Air pressurization from three ring-shaped bottles at 4,000 Lb./in.^{2}, reduced to 512 Lb./in.^{2} in tanks.

(3) *Combustion chamber.*—Operating pressure: 270 Lb./in.^{2}; 5·5 in. diameter. L*: 160 in. Nozzle throat: 1·625 in. diameter. Expansion cone 12° half angle. Carbon inner, ceramic filler and steel outer, 0·25 in. thick. Nozzle carbon erodes during use, chamber pressure drops to 120 lb./in.^{2} L* decreases to about 100 in.

(4) *Injectors.*—Three equally-spaced injectors on flat head end. Each with impinging jets, fuel outer cylindrical spray, with inner 90° cone of peroxide spraying into it. Developed from Walter 109-509 designs.

(5) *Cooling.*—None.

(6) *Ignition.*—Although self-igniting propellants used, several explosions occurred at high altitude due to long ignition delay. An electrically-fired solid propellant torch igniter finally fitted.

(7) *Starting sequence.*—Starting valve operated electrically by impulse from clock-operated sequence control, 6 sec. after vehicle release from carrier. Polyvinylchloride bursting discs used in both propellant lines immediately before chamber. Peroxide was delayed by using soluble chemical restrictor in line.

(8) *Weight.*—Complete power unit with tanks full about 500 lb.

(9) *Operational details.*—Design and development started in late 1945. Ready for first flight test in May, 1947. Various failures, primarily with ignition. Final test October, 1948, engine operation successful.

* Royal Aircraft Establishment.

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(2) K. W. Gatland: Data Sheets, *J.B.I.S.*, **14** (4), 232 (July–August, 1955).
(3) E. Burgess, "Rocket Power," *Aeronautics*, **18** (6), 46 (May, 1948).
(4) "Operation Neptune," *Flight*, **52** (2025), 446–448 (October 16, 1947).

DATA SHEETS

By K. W. Gatland, F.R.A.S.

HONEST JOHN—United States of America—Douglas Aircraft Co.

(*a*) Rôle: surface-to-surface, bombardment (field artillery rocket).
(*b*) Origin: 1951 (initial firing).
(*c*) Length: 28 ft.
(*d*) Diameter, body (max.): 2 ft. 6 in.
(*e*) Diameter, over fins: 8 ft.
(*f*) Diameter, over wings: not applicable.
(*g*) Weight, launching: 6,000 lb. (approx.).
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: not available.
(*k*) Thrust: not available.
(*l*) Velocity (max.): Mach 1·5.
(*m*) Altitude: not available.
(*n*) Range: 20 miles.
(*p*) Propellant: large solid-propellant unit (Hercules Powder Co.).
(*q*) Feed system: not applicable.
(*r*) Control: none, arrow stability by four fixed fins.
(*s*) Booster: none.

Honest John.

Notes: Weapon system; free-flight artillery rocket and mobile, self propelled, launcher. Missile comprises large-calibre motor tube with four tail fins and a bulbous ballistic nose containing warhead (either conventional H.E. or atomic). Rocket not supplied complete to field units, motor tube, fins and warhead being assembled close to launching site. Normal crew training and standard artillery "gun-laying" technique employed. Replacement for 280 mm. "atomic cannon."

History of project: design study initiated by U.S. Army Ordnance, May, 1950; proposals based on Ordnance specification submitted by Douglas Aircraft and accepted; initial firing trials completed, White Sands, August, 1951—justified production of additional models; further successful tests with improved models manufactured by Douglas and fired from self-propelled launchers developed by Army Ordnance, Jan. 1953. Contracts placed for large-scale production. Douglas Aircraft Co. (overall missile), motor tube (Alco Products, Inc.), and Hercules Powder Co. (propellant).

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(1) "Missile directory," *Aero Digest*, **69** (1), 31–36 (July, 1954).
(2) "Development of the Guided Missile," by K. W. Gatland (2nd edition), Iliffe & Sons, London, 1954.

CORPORAL (SSM-A-17)—United States of America—Douglas Aircraft Co.

(*a*) Rôle: surface-to-surface, bombardment (tactical artillery rocket).
(*b*) Origin:
(*c*) Length: 40 ft. approx.
(*d*) Diameter, body (max.): 2 ft. 6 in.
(*e*) Diameter, over fins: 6 ft. 3 in.
(*f*) Diameter, over wings: not applicable.
(*g*) Weight, launching: 11,000 lb. (approx.).
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: not available.
(*k*) Thrust, not available.
(*l*) Velocity (max.): Mach 3·0.
(*m*) Altitude: not available.
(*n*) Range: 150 miles (max.).
(*p*) Propellant: not available.
(*q*) Feed system: not available.
(*r*) Control: gyro-controlled exhaust vanes/beam rider guidance system. Four tail fins giving arrow stability during descent on target.
(*s*) Booster: none.

Corporal.

NOTES: Weapon system: guided artillery rocket, mobile launcher (incorporating erector and launching pedestal) and beam-guidance transmitter. Self-propelled, hydraulically-operated, erector places missile in vertical firing position on pedestal.

Guide-beam accurately laid on target in azumuth at given angle of elevation; missile embodies controls which enable it automatically to seek the axis of the guide-beam whilst under propulsion. Range depends on precise determination of missile's velocity (at requisite beam angle) at cut-off point, missile thereafter following ballistic trajectory to target. Warhead either conventional H.E. or atomic.

History of project: California Institute of Technology awarded U.S. Army Ordnance contract to investigate development of artillery-type rockets (early 1944)—resulted in test-vehicles Private 'A,' Private 'F' and WAC Corporal (1944-1945); establishment of Jet Propulsion Laboratory (an Army Ordnance installation operated under contract by California Institute of Technology) and contract to undertake full-scale guided-missile programme; Corporal 'E' preceded present model of Corporal. Successful tests of final weapon manufactured by Firestone Tyre and Rubber Co. in conjunction with mobile launcher developed by Army Ordnance. Contracts placed for large-scale production. Firestone (overall missile) Ryan Aeronautical Co., (rocket engine) and Gilfillan Brothers, Inc. (guidance).

REFERENCES

(1) "Guided Missiles," *Aero Digest*, **70** (3), 22–25 (March, 1955).
(2) "Missile Directory," *Aero Digest*, **69** (1), 31–36 (July, 1954).
(3) "Development of the Guided Missile," by K. W. Gatland (2nd edition), Iliffe & Sons, London, 1954.

SPARROW 1 (AAM-N-2)—United States of America—Sperry-Farragent Corp.

(*a*) Rôle: Anti-aircaraft, air-to-air.
(*b*) Origin: 1948 (initial firing).
(*c*) Length: 8 ft. 3 in.
(*d*) Diameter, body (max.): 6 in.
(*e*) Diameter over fins: 2 ft.
(*f*) Diameter over wings: 2 ft. 3 in.
(*g*) Weight, launching: 280 lb.
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: not available.
(*k*) Thrust: not available.
(*l*) Velocity (max.): Mach 3·0.
(*m*) Altitude: not applicable.
(*n*) Range: 4 miles.
(*p*) Propellant: solid, double-based.
(*q*) Feed system: not applicable.
(*r*) Control: wings, gyro-controlled/beam rider guidance system with semi-active radar homing.
(*s*) Booster: none—air-launched.

Sparrow 1.

NOTES: Developed jointly by U.S. Bureau of Aeronautics and Sperry-Farragent Corporation. Over 100 test-firings made between 1948 and 1951, including ground firings in conjunction with solid-propellant boosters and air-launchings from a Douglas F3D Skynight (U.S.N.).

Manufacturers: Douglas Aircraft Co. (overall project and airframe), Sperry and Raytheon Manufacturing Co. (control and guidance equipment). Also, Sparrow 2 (AAM-N-3); Sparrow 3 (AMM-N-6) and Sparrow 4, differing mainly in guidance equipment.

REFERENCES

(1) "Guided Missiles," *Aero Digest*, **70** (3), 22–25 (March, 1955).
(2) "Missile Directory," *Aero Digest*, **69** (1), 31–36 (July, 1954).
(3) "Development of the Guided Missile," by K. W. Gatland (2nd edition), Iliffe & Sons, London, 1954.

FALCON GAR-98—United States of America—Hughes Aircraft Co.

(*a*) Rôle: anti-aircraft, air-to-air.
(*b*) Origin: 1950 (at Hughes).
(*c*) Length: 6 ft.
(*d*) Diameter body (max.): 6 in.
(*e*) Diameter over fins: 10 in. (nose vanes).
(*f*) Diameter over wings: 1 ft. 6 in.
(*g*) Weight, launching: 128 lb.
(*h*) Weight, propellant: not available.
(*j*) Weight, payload: not available.
(*k*) Thrust: 6,000 lb × 1 sec.
(*l*) Velocity (max.): 1,360 m.p.h. (plus speed of launching aircraft).
(*m*) Altitude: not applicable.
(*n*) Range: 4 miles.
(*p*) Propellant: Solid (Thickol Chemical Corporation).
(*g*) Feed system: not applicable.
(*r*) Control: aerodynamic nose vanes, gyro-controlled/beam rider guidance system with semi-active radar homing.
(*s*) Booster: none: air-launched.

NOTES: In study phase (1947), project formerly known as Dragonfly and sponsored by General Electric Company; contract awarded to Hughes Aircraft Co. in 1950 to develop operational weapon for U.S.A.F.

Falcon

Glass-fibre reinforced phenolic plastic used in manufacture of body, wings and stabilizers. Guidance system developed by Hughes. Also, Falcon II and III, differing mainly in guidance equipment.

Aircraft operating this weapon include: Northrop F-89H, Lockheed DF-94C and Convair DF-102.

REFERENCE

(1) "Operational Missiles now Arming U.S.A.F," by R. Hotz, *Aviation Week*, **62** (12), 14–17 (March 21, 1955).

Silhouettes by M. F. Allward

B.I.S. ANNUAL DINNER

When the Second International Astronautical Congress was held in London in 1951, the final item in the proceedings was a dinner given at St. Ermin's Hotel in honour of the various foreign delegates. More recently, in October 1954, another dinner was held at the Waldorf Hotel to mark the 21st anniversary of the Society's foundation; this was even more successful, over 200 persons attended and many more applications had to be refused because of space limitations. Ever since, the Council has from time to time received requests from members that a dinner should be held annually.

To meet this demand a dinner has been arranged on Saturday, March 17; if this is successful it will then be possible to establish it as an annual event. It was thought, however, that a less formal function than the previous ones might well be desirable, and with this in mind accommodation will be limited to only 80 persons, the cost of the tickets has been kept down to one guinea each, and there will be no speeches. The dinner will be held at the Craven Hotel, Craven Street, Strand, W.C.2, which is very centrally situated, being only one minute's walk from Trafalgar Square. In addition to the large room in which the dinner itself is to be held, a lounge bar has been reserved for the use of members and their guests before and after the meal, while a cocktail bar and other facilities will also be available. Members from the provinces or from overseas who wish to attend the dinner will be able to obtain accommodation at this and several other hotels close by at reasonable prices.

In view of the limited accommodation, early application is advisable, and all requests for reservations should be sent with remittances to the Secretary. We hope to achieve a very friendly and intimate atmosphere; dinner jackets will be optional.

Please note the following details:

Date and time: Saturday, March 17, 7.30 to 11.30 p.m.
Place: Craven Hotel, Craven Street, Strand.
Tickets: £1 1s. each (remittance with reservation to Secretary, B.I.S., 12, Bessborough Gardens, London, S.W.1).

TECHNICAL REVIEW

A New Estimate of the Moon's Atmosphere

Estimates of the density of the Moon's atmosphere, if it has one, are usually of a negative kind, and consist of statements that it cannot be denser than some particular figure or it would have been discovered by now. And the figure is usually exceedingly small.

For instance, when the Moon passes in front of a star, the star vanishes so suddenly that, it is estimated, the density of any atmosphere the Moon may have cannot be more than 1/10,000th of that of the Earth's atmosphere at sea level. But at the height where most meteors burn up, at about 50 miles, our own atmosphere is less than 1/10,000th as dense as at sea level, so it would still be possible for the Moon's atmosphere to be dense enough to destroy meteors before they could reach its surface, and yet not be dense enough to show its presence during the occultation of stars.

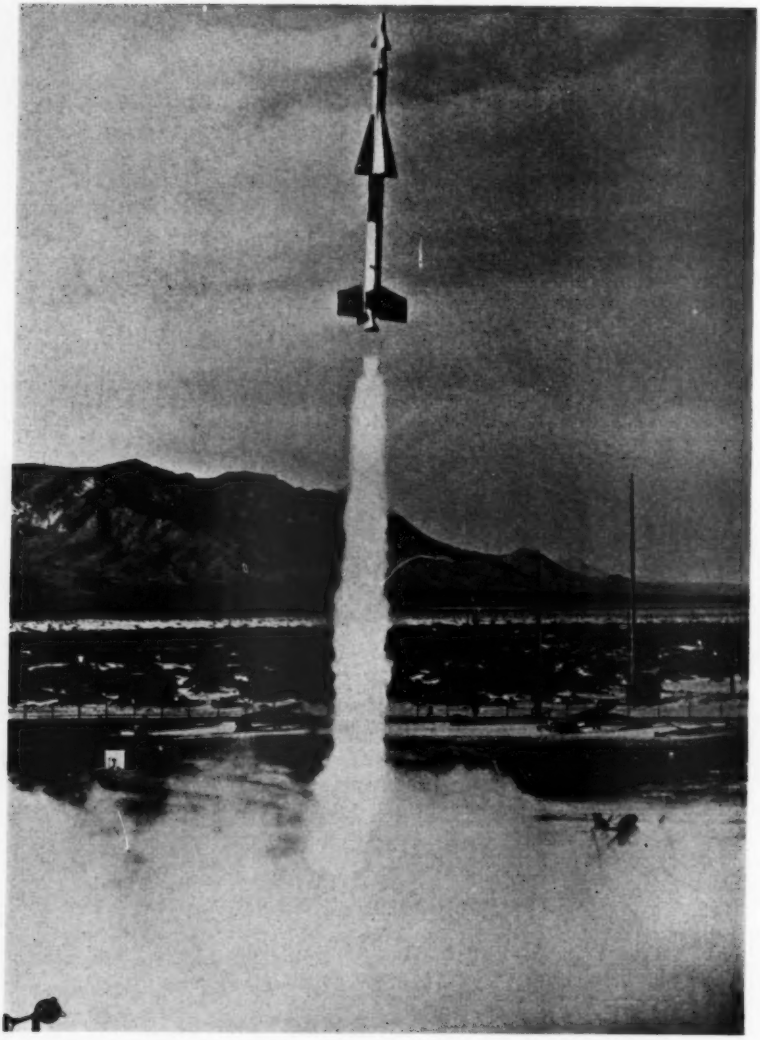
There have been occasional reports of flashes of light seen on the Moon, and they could, if genuine, be caused by meteors either hitting the Moon or being disintegrated in its atmosphere. But no permanent changes on the Moon's surface which could definitely be attributed to meteors appear to have been recorded. Smoke particles ejected from the surface would, if there were no atmosphere, fall back as fast as gravity could pull them; but their fall would be delayed by an atmosphere, and appearances suggesting the delayed fall of a dust cloud have occasionally been seen.

Now a new method has been found of estimating the density of the Moon's atmosphere—or rather, of finding the maximum density it could have without being detected. Instead of watching the disappearance of a visible star behind the Moon, this time a radio star has been observed.

Two radio astronomers at Cambridge, G. R. Whitfield and B. Elsmore, watched a radio source in the constellation of Gemini, of rather wide diameter, as it disappeared and reappeared behind the Moon on the afternoon of April 26, 1955, the Moon being then four days "old." It is known as No. 2C.537 of the Cambridge survey, and evidently gives out visible light as well, as its position is identical with that of galactic nebulosity known as *IC*.443, which has been photographed by the Schmidt camera at Palomar.

The important part of the experiment came at the time a particularly bright filament, giving radiation five times as strong as the average from the radio "star" as a whole, emerged from behind the Moon. According to theory, its detection by the radio telescope would be delayed about one minute by diffraction at the Moon's limb, and a further amount of refraction in the Moon's atmosphere. Elsmore and Whitfield describe their conclusions thus in *Nature* (**176,** 458, Sept. 3, 1955).

> "The observations show that the total delay cannot exceed 4 min., and the electron density in the lunar atmosphere cannot then exceed 10^5 per c.c. if the scale-height lies in the range 50–1,500 km. Although the composition may differ considerably from the terrestrial atmosphere, it seems probable that, on the Moon's sunlit side, the degree of ionization would be as great as that



Nike Guided Missile

The "booster" rocket has started the "Nike" on its supersonic quest for a flying target. After the initial thrust the booster falls away and the missile proper continues towards the target, guided by electronics from the ground.

of the *F*-region. On this supposition the density of the lunar atmosphere must be less than 10^{-12} of the density of the terrestrial atmosphere at sea level, a figure 1/1,000th of the previous upper limit derived by Dollfus from optical measurements."

In other words, the Moon's atmosphere cannot be more than a million-millionth as dense as that of the Earth at sea level. This would stop no meteors. However, Mr. Whitfield has told the present writer that they consider their results rather tentative, and intend to have several more tries at similar experiments whenever opportunity offers.

This particular experiment appears not to have been tried by radio astronomers before. Perhaps Mr. Whitfield's interest in the Moon's atmosphere derives from the fact that he is a leading member of Cambridge University Gliding Club.

"Nike" Guided Missile

The "Nike" is a supersonic anti-aircraft rocket named after the famous "Winged Victory" of Greek mythology. It is a pencil-shaped missile capable of intercepting and destroying enemy aircraft regardless of evasive action, and was developed by a service-industry team composed of engineers of the Army Ordnance Corps, Western Electric Company, Bell Telephone Laboratories and Douglas Aircraft Company.

Mass production of the control equipment was undertaken by the Western Electric Company, while the rockets and components of the associated ground-handling equipment were produced by Douglas Aircraft Company.

"Nike," itself, is a two-stage rocket classified as a surface-to-air weapon. It is dart-like, about 20 ft. long and 1 ft. in diameter, with sharply-swept cruciform fins near the nose and similar fins near the after end. The missile is attached to a booster section which also has stabilizing fins at the base. After a period of initial thrust which attains supersonic speed, the booster portion drops off and a sustaining rocket motor contained in the missile takes over. An explosive warhead and electronic guidance equipment are also carried in the body of the basic missile. As a safety measure, the warhead is designed to explode only when in flight.

The rocket is an integral part of a complex spotting and guidance system which electronically picks up and tracks a target 'plane and automatically launches a rocket at the proper moment to intercept the aircraft, regardless of weather conditions or visibility.

"Nike" may be employed either from fixed or mobile battery installations. All of its units, except steel launching racks, are housed in all-weather van-type trailers, and the entire system is designed to be transportable by air.

The "Nike" project was initiated in 1945 when Army Ordnance asked Bell Telephone Laboratories to undertake a study of the problems involved in the construction of a new anti-aircraft system. As a result of their recommendations, the Army authorized a development contract so that the envisioned guided missile system could be brought to a reality. Douglas then became a full partner in the enterprise and was assigned responsibility for about half the development effort, including design of the missile and the launching equipment.

Nearly five years were required to solve the new and complex technical problem posed by the "Nike" system. During this time, test firings to improve launcher and booster designs were made at the White Sands Proving Ground in New Mexico. Meanwhile, development of the guidance equipment proceeded at Bell Laboratories.

Scenes of the Earth from a "Viking" Rocket

"Viking" No. 11 fired from White Sands Proving Ground, New Mexico, on May 24, 1954, made a record breaking climb of 158 miles above the Earth and reached a maximum speed of 4,300 m.p.h.

An aerial camera installed in the rocket took a number of photographs which are notable for their extreme clarity and detail, and which are reproduced on the following pages.

The "Viking" is built for the U.S. Naval Research Laboratory by the Glenn L. Martin Co., Baltimore, and powered by a 21,000-lb. thrust engine built by Reaction Motors Inc. This 7½-ton, 45 ft. long research vehicle carried half a ton of scientific instruments.

Dustball Meteors

Dr. E. J. Öpik, of Armagh Observatory, who believes that many meteors come from outside the solar system, has made yet another addition to his original ideas on the subject of meteors, upon which he has been working for most of his astronomical career.

He has now come to the conclusion that most of the visual meteors, which we see disintegrating in a blaze of light, are not single solid stones, as has been almost universally believed hitherto, but "fluffy or spongy objects, of low average density and loosely-bound, which break up under a relatively low aerodynamic pressure of about 10^4 dyne/cm^2."

Öpik gives his reasons in an article "Meteors and the Upper Atmosphere," in the *Irish Astronomical Journal*, **3**, 165 (June, 1955). His chain of reasoning is too complicated to reproduce here, but he finds that most of the visual meteors, as well as those bright enough to be photographed which burn out at heights above 90 km. (56 miles), must have such large cross-sections in relation to their mass that they cannot possibly be solid lumps of stone. Only those which are able to penetrate below 80 km. (50 miles) can be of solid stone.

Assuming that the larger celestial bodies were formed by the agglomeration of smaller ones, Öpik suggests that their original building material was the "fluffy stuff" of which he supposes most meteors to consist, and it only became dense when put under pressure. Solid meteors are presumably the remnants from disintegration of larger bodies.

It should be explained that Öpik bases his calculations on the density of the atmosphere as recorded by rocket-borne instruments at the heights where meteors disintegrate. It is because these densities are so much less than those previously calculated from meteor observations on the assumption that all meteors are solid, that he has been driven to propound his "dustball" theory. If it becomes generally accepted, present calculations about meteor penetration of space vehicles will evidently have to be done all over again.

At an altitude of 146 miles, Roosevelt Lake in Arizona appears as a thin black vertical line in the upper left-hand corner of the picture and is 325 miles away. The Colorado River may be seen at the upper left-hand corner of the picture; there are no large cities in this view, which looks to the north-west (top of picture).

158 miles high. The Rio Grande and the cultivated areas along its borders run diagonally across the lower left-hand corner of the photograph. More than half of the area shown is in Mexico. The camera (and the top of the photograph) points southward.

Approximately 600,000 square miles of the Earth—mainly in Texas and Mexico—are shown in this photograph. Two photographs taken 30 seconds apart were combined to give this composite view. The photograph on the left was taken at 155 miles, that on the right at 138 miles. From the camera to the horizon is approximately 1,100 miles, and the section of the horizon shown spans about the same distance. The camera is looking S.S.E. from Texas across into Mexico. Mexico City is just on the horizon in the middle of the photograph. The Gulf of Mexico is on the left-hand side (covered by clouds) and the Pacific Ocean on the right. A well defined cold front extends from the left-hand corner and runs parallel to the curvature of the Earth.

Earth *v.* Beetle

In a colloquium on "Polar Wandering," held recently at Cambridge University, Mr. T. Gold, of the Royal Greenwich Observatory, is reported by *Nature* (**176**, 424, Sept. 3, 1955) to have said that:—

> "A movement of the entire Earth relative to the poles of rotation can be achieved by internal effects; only the vector of angular momentum has to remain fixed in space. If we have a stationary sphere resembling the Earth, a beetle weighing one gram could turn it over once by walking 10^{27} times around it. If instead we have a rotating sphere, then the beetle can cause any desired angle of movement of the poles relative to the sphere by merely sitting in the right place."

One day—who knows?—somebody will meddle with the celestial mechanics of the solar system by walking round and round a small asteroid.

NOTES AND NEWS

March, 1956, London Lecture—A Correction of Date

The printed Lecture Programme issued to all members quotes the date of the lecture by Professor A. D. Baxter as 7th March, 1956. This was a misprint, as the correct date is *3rd* March, 1956, i.e. the first Saturday in the month, as is the normal practice for London meetings.

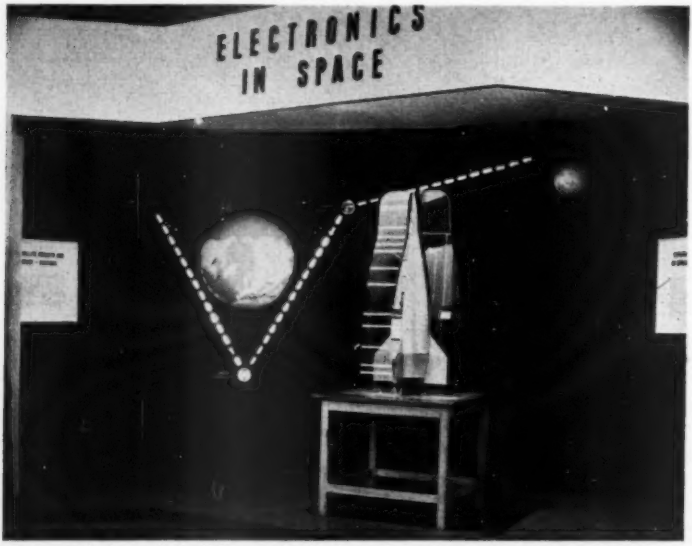
Australian Rocket Exhibition

Approximately 35,000 people visited the Weapons Research Exhibition, which was held in Adelaide on October 21 and 22, 1955.

The Guided Weapons Contractors exhibited a fair amount of auxiliary unclassified equipment, but this was subject to the same restrictions as for U.K. parent concerns. An educational telemetry stand for the layman was outstanding, demonstrating the channel measurements on transmitter and receivers used in rocketry.

Some important associated rocket engineering functions were as follows:

1. Theatrette—with a continuous performance of a film, *The Australian Guided Weapons Range*. This was in colour and showed the whole function, firing, general personnel, and conditions at Woomera and Salisbury.
2. Optical and mechanical instrumentation; and upper atmosphere research.
3. Telemetry and aerial display.
4. Transistors: "Professor W. R. E. Quiz," an electronic puppet.
5. Kine-theodolite van.
6. "Jindivik" pilotless aircraft.
7. Electronic measuring equipment; speed of a golf ball.
8. Model of a wind tunnel.
9. Supersonic test showing shock waves on a screen.
10. Rocket display. Research test vehicle on a launcher; recovered components.
11. Radar speed checks, etc.



A general view of the "Electronics in Space" exhibit at the 1955 Radio Show.

RADIO SHOW, 1955.

Messrs. M. F. Allward and F. S. C. Atkey discuss points with the designer of the exhibit, Mr. K. W. Gatland (*right*).

The exhibition was very well organized, with Army M.P.s, a military band, and Air Force personnel, in attendance. The main exhibition thoroughfare was bedecked by rockets on the ends of flagpoles and fairy lights.

This effort was again a credit to a small community and one wonders what the first British official exhibition will be like.

Astronautics at the 1955 Radio Show

At the Radio Show, held at Earl's Court from August 26 to September 3, astronautics was represented for the first time in a display which depicted the uses of artificial satellites. The exhibit was designed, on behalf of the British Interplanetary Society, by Kenneth W. Gatland, whose work in conjunction with Messrs. A. M. Kunesch and A. E. Dixon led to the original design specification for the MOUSE project (*see* "Minimum Satellite Vehicles," *J.B.I.S.*, **10**, 287-94, Nov. 1951).

The main display—a synthesis of several satellite applications—illustrated the use of Earth-satellites as scientific observatories, television relays and meteorological stations; an unmanned satellite probe was also shown in a circumlunar orbit. A novel feature was the suggestion that an unmanned probe rocket, acting as a lunar satellite, might obtain close-up pictures of the Moon's surface, including areas obscured from the Earth, by means of a facsimile reproduction (i.e., a technique similar to that employed for the transmission of news-pictures "by radio"). Television, it was emphasized, would be more complex and require greater powers.

The various satellites were linked on the display panel by a sequence of illuminated arrows, indicating the transmission of radio signals between the Moon and the Earth, via the Earth-satellites.

A 4-ft. model of a three-step rocket, with the lunar probe at its head, was fully sectioned to reveal internal detail.

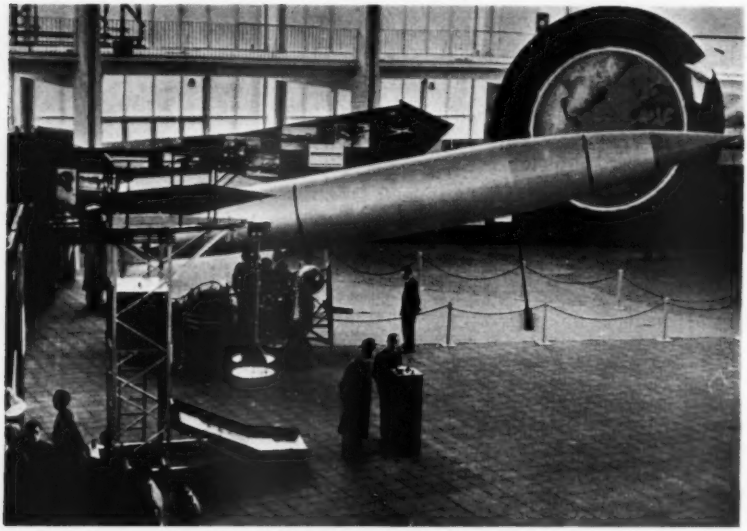
B.I.S. Lecture Posters

A number of large posters advertising the Society's London lectures are now available, and members who could use them for display purposes are invited to write to the B.I.S. Secretary for copies.

Lectures of Interest

Three lectures of special interest to B.I.S. Members are included in a University Extension Course on "Recent Developments in Meteorology," to be given at the Imperial College of Science. They will be given by Dr. R. M. Goody, M.A., Ph.D., Reader in Meteorology at Imperial College, and author of *The Physics of the Stratosphere*. On March 15 and 22, Dr. Goody's subject is "Upper Air Rocket Research," and on March 29, "The Meteorology of Mars."

The lectures are on Thursdays at 6.30 p.m., in Huxley Building, opposite the Science Museum in Exhibition Road, South Kensington. The fee is 2s. for a single lecture, or 15s. for the whole course, which begins on January 12, 1956.



DEUTSCHES RAKETEN–UND RAUMFAHRTMUSEUM

Preparations for an exhibition in Karlsruhe, 1952. In the background is a globe used to show space station orbits proposed by Dr. Merten.

DEUTSCHES RAKETEN–UND RAUMFAHRTMUSEUM

Exhibition arranged in Vienna, 1955. On the right is the combustion chamber of an A-4 rocket.

Nominations for Council 1956-57

In accordance with the provisions of Article 15 of the Society's Constitution; one-third (i.e., *four*) Members of the Council (Messrs. D. Hurden, D. F. Lawden, A. E. Slater and R. A. Smith) will retire from office at the Eleventh Annual General Meeting, which will be held on Saturday, April 21, 1956, at the Kent Room of Caxton Hall, London, S.W.1, commencing at 6 p.m.

Nominations are invited from members for election to the Council for next session. The procedure is outlined in Article 16, which requires that signed nominations must be provided by a member qualified to attend and vote at the meeting, and also a notice in writing must be submitted by the person nominated confirming his willingness to be elected.

Suitable forms can be obtained on application from the Secretary, and should be completed and returned as soon as possible, in any event not later than March 17, 1956.

If the number of nominations exceeds the number of vacancies, election will be determined by postal ballot and voting papers will be prepared and forwarded to all members for completion and return before the date of the meeting.

Deutsches Raketen—und Raumfahrtmuseum

In September, 1952, the Gessellschaft für Weltraumforschung staged a most successful Exhibition on "Rockets and Space-Flight" in conjunction with the Third International Astronautical Congress, which was held in Stuttgart at that time, and it was decided at a later Board meeting on November 1, 1952, to retain the exhibits on a permanent basis.

Accordingly, the "Deutsches Raketen—und Raumfahrtmuseum" (German Rocket and Space Flight Museum) was founded for this purpose, and was greatly assisted by various firms and individuals who helped in procuring exhibits.

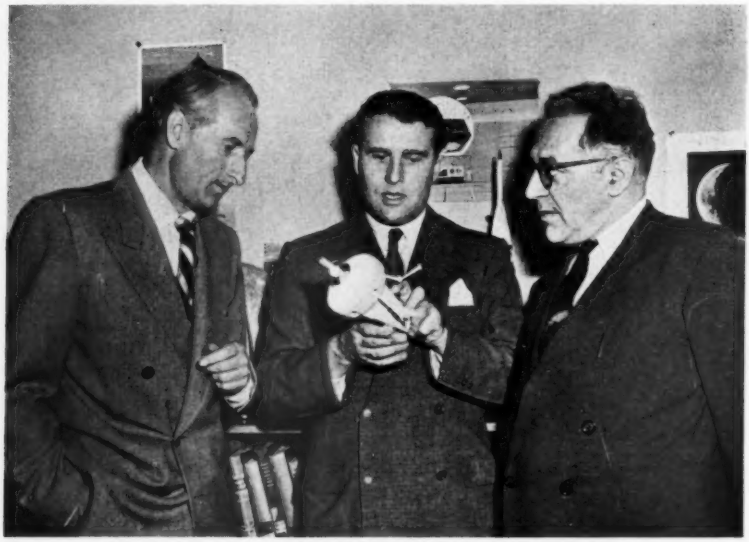
The Museum is controlled by a Board of Trustees and a Council, and has at present a membership of 62, most of whom have, in one way or another, furthered its objects. It has an office in Stuttgart-W, Reinsburgstrasse 54, and storage space at Schnit near Stuttgart, and hopes to have permanent exhibition rooms within the next few years.

Among its exhibits are a complete A-4 rocket and a cross-section of the A-4 rocket power plant, together with many smaller rockets and about 50 models, including sounding rockets, rocket 'planes, satellite rockets, launching sites, space-suits, and celestial globes. In addition it has about 100 diagrams and astronautical drawings in colour, and a further 100 large and 200 medium and small photographs.

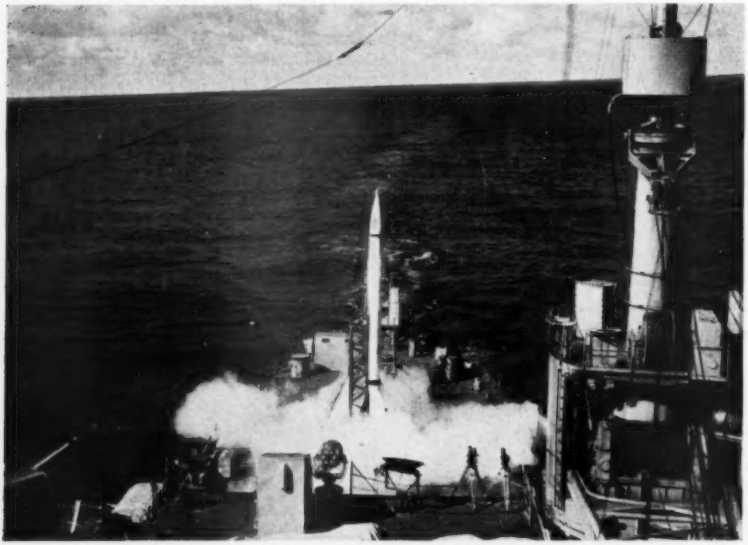
The exhibits have been loaned out to many exhibitions arranged in Germany and other countries, and have attracted much attention.

The Museum derives its revenue from subscriptions and donations, which average £1/2,000 per annum, but this does not include donations of materials and specially manufactured articles by firms.

The Museum is anxious to expand its collection and would like to contact all who can provide it with interesting historical material.



Heinz Haber, Wernher von Braun and Willy Ley discuss the model of a so-called "bottle-suit" (for assembly work in space) in the Disney studios.



Viking 4 being launched from aboard the U.S.S. *Norton Sound*.

Disney Films on Space Travel

Three films on space travel are being prepared by Walt Disney Productions, with the assistance of Willy Ley, Wernher von Braun and Heinz Haber. The first, dealing with the development of astronautics from early Chinese fire rockets to the unmanned satellite, was screened on the U.S. TV (ABC network) last spring; the second, concerned with flights to the Moon, appeared last autumn; and the third, which will describe the Mars project, will be available in the spring of 1956. Although all three are being screened on TV, they are filmed in technicolour and will eventually be shown in cinemas, probably as a single picture running for 80-100 minutes.

Midlands Branch Models Group

The Branch exhibition material, which consists of models, paintings, and photographs, has been seen by thousands of people both in the Midlands and in other parts of the country. It is in frequent and ever-increasing demand, and considered a most important activity in the publicity of the Society.

These exhibits represent the work of a very small number of people spread over several years, and many more "man-hours" are required to keep it up-to-date and to extend its scope. Not only are members required to assist who may be interested in model-making, but others are needed also who may have a flair for any of the following:—drawing, illustrating, poster-work, lettering, printing, photography, instrument-making, optical systems, "gadgets," astronomy, etc.

All interested in actively in assisting the work of this group should write to the Chairman, Mr. N. R. Nicoll, 93, Leighswood Avenue, Aldridge, Staffs.

Astronautical Interest in France

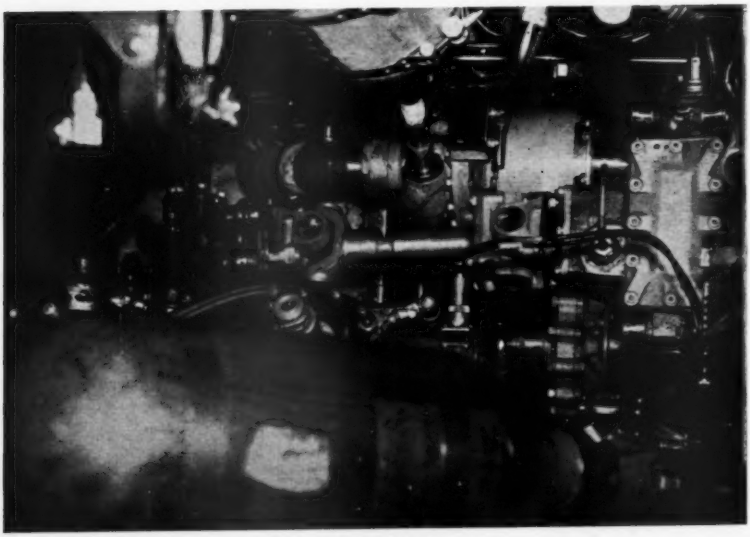
The *Association pour l'Encouragement a la Recherche Aéronautique* held a most interesting Congress in Paris on October 14 and 15, 1955, at which a total of 23 films was presented on the subject of guided missiles, rockets, radar, and certain medical problems of high-speed flight. The Congress was attended by about 300 persons, and received a fair amount of publicity in France.

In addition to the films, two short talks were given and our Secretary, Mr. L. J. Carter, read a speech prepared by the Society's Chairman, Dr. L. R. Shepherd, expressing the interest of the B.I.S. in all activities which might lead to the growth of interest in astronautics in France and the eventual creation of a French astronautical group.

The A.E.R.A. was founded on June 24, 1949 by M. Jean Venturini (its President) and now has 200 members. It has held a number of Congresses since that date with the assistance of Universities, Industrial Establishments, etc. In June 1950 it held a Congress on vibration, in February 1951 a Congress on heat-resisting materials, and in late 1955 an International Congress on materials for aviation and rocket projectiles, the proceedings of which are to be published in a special 1,200 page (9000 francs) volume. The A.E.R.A. will also soon arrange for the publication of a "Monograph on Rocket and Guided Missiles," 350 pages (3500 francs).

M. Pierre Lefranc is the Secretary-General and the address is 1, Rue de Courty, Paris, 7e, France.

Fuelling Snarler in Hawker P1072 aircraft.



Snarler installed in aircraft.

The Armstrong-Siddeley "Screamer"

Armstrong-Siddeley recently announced that they have under development a new liquid-propellant rocket engine known as the "Screamer." Test-bed trials have been running for some time, and preparations for flight trials are now nearly complete.

The new engine, applied to aircraft, opens up possibilities of extremely high altitude and high speed performance. It will be remembered that Armstrong-Siddeley's developed the "Snarler" (of 2,000 lb. thrust using liquid oxygen and methanol-water mixture as fuel), which flew in the Hawker P1072 in 1950 and 1951. Two pictures arising from these experiments appear on page 50 (opposite).

ROCKETS. Manufacturers of Rocket Propulsion Engines have two vacancies for Mechanical Engineers for the design of test equipment. Applicants must have a Degree or HNC. Salary £700–£850, depending on experience. Three vacancies for Electronic Engineers. Applicants must have at least a HNC. Salary £600–£750. Applications quoting ME/EL/R to Box No. EC100.

Box No. replies should be sent to:—

Technical Personnel Manager,
Armstrong-Siddeley Motors, Ltd.,
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ABSTRACTS

Edited by J. HUMPHRIES

A further addendum to the list of abbreviations included in the 1954 index is given below.

G.-E. Rev.	G.-E. Review.
Prob. Astr. Grund.	Probleme aus der Astronaustischen Grundlagenforschung (Proceedings of the Third International Astronautical Congress).
Tec. Ital.	Tecnica Italiana.

AERODYNAMICS

(1) **Use of aerodynamic heating to provide thrust by vaporization of surface coolants.** W. E. Moechel. *N.A.C.A. Tech. Note No.* 3140, 37 pp. (*Feb.*, 1954). Analysis of the thrust and specific impulse attainable by cooling aircraft structures with liquefied or solidified gases having vaporizing temperatures lower than the equilibrium temperature. (10 *refs.*)

(2) **Engineering relations for friction and heat transfer to surfaces in high velocity flow.** E. R. G. Eckert, *J. Aero. Sci.*, **22**, 585-7 (*Aug.*, 1955). Simplified relationships for use at Mach numbers up to 18 and heights up to 30 miles. (8 *refs.*)

AIRCRAFT

(3) **Some fundamental problems of vertical take-off.** E. Bachem. *Prob. Astr. Grund*, 89-96 (*Oct.*, 1952) (*in German*). A survey of the design and development of the "B.P. Natter," a vertically-launched piloted missile-aircraft.

(4) **Comparison of model and full-scale spin recoveries obtained by use of rockets.** S. M. Burk and F. M. Healy. *N.A.C.A. Tech. Note No.* 3068, 63 pp. (*Feb.*, 1954). Comparison of tests on one-nineteenth scale model in a spinning tunnel and on full-scale aircraft in free flight.

(5) **Rocket engines for aircraft.** A. D. Baxter. *Aeroplane*, **88**, 211-2 (*Feb.* 18, 1955).

ASTRONAUTICS

(6) **Space-flight—a problem for international scientific co-ordination.** W. von Braun. *Prob. Astr. Grund.*, 246-256 (*Oct.*, 1952) (*in German*). A recommendation that the interplanetary societies of the world should devote their attentions to fields of investigation being neglected by the military scientist, giving examples of such problems.

(7) **Establishment of large satellites by means of small orbital carriers.** K. A. Ehricke. *Prob. Astr. Grund.*, 111-145 (*Oct.*, 1952). Gives reasons for the use of an auxiliary orbit and small ferry ships to construct and supply an orbital base. Recommends carriers to work between surface and the auxiliary orbit, from which a single ferry craft transfers multiple loads to the satellite base. Considers orbital transfer problems, and effect of aerodynamic deceleration and gives detailed weight analysis.

(8) **Fundamentals on the question of unmanned and manned space vehicles.** A. Hjertstrand. *Prob. Astr. Grund.*, 70-73 (*Oct.*, 1952) (*in German*). Investigates the improvement of multi-step rocket performance which can be derived from constant acceleration powered flight.

(9) **The satellite rocket, 1952.** H. Hoeppner. *Prob. Astr. Grund.*, 97-105 (*Oct.*, 1952) (*in German*). A continuation of the work on Satellite Rocket 51, in particular concerned with launch and launchers, safety considerations, and structural details.

(10) **Secular perturbations of an artificial satellite orbit.** H. G. L. Krause. *Prob. Astr. Grund.*, 162-173 (*Oct.*, 1952) (*in German*). A method for investigating secular perturbations of satellite orbits of any eccentricity and inclination about an oblately spheroidal planet. Measurements on an unmanned satellite can check the general theory of relativity. (6 *refs.*)

(11) **Catapult start.** H. Kühme. *Prob. Astr. Grund.*, 106-110 (*Oct.*, 1952) (*in German*). The advantages of a catapulted launch for satellite rockets are shown. Present catapults could be adopted for rockets up to 20 tons weight, and a vertical launch is advisable.

(12) **Inter-orbital transfer of a rocket.** D. F. Lawden. *Prob. Astr. Grund.*, 146-161 (*Oct.*, 1952). (Also in *J. Brit. Interplanet. Soc.*, **11**, 321-333 (1952)). Transfer between coplanar orbits about a centre of inverse square law attraction, the time of transit being unspecified. (9 *refs.*)

(13) **Legal problems of space-flight**. A. Meyer. *Prob. Astr. Grund.*, 19-29 (*Oct.*, 1952) (*in German*). Deals with legal problems raised by space-flight and the establishment of satellite stations. (17 *refs.*)

(14) **The trajectory of a low acceleration rocket in a central gravitational field.** H. F. Michielsen. *Prob. Astr. Grund.*, 174-180 (*Oct.*, 1952) (*in German*). Those spaceships which penetrate far into space will need propulsive units which give only low thrust. This paper deals with the trajectories of bodies acted on by a gravitational field and a small thrust, in particular the spiral trajectory.

(15) **Private work in space-flight**. H. Oberth. *Prob. Astr. Grund.*, 11-19 (*Oct.*, 1952) (*in German*). Encourages individuals and private organisations to devote themselves to work on astronautical problems.

(16) **Basic astronautical research on an international basis.** J. A. Stemmer. *Prob. Astr. Grund.*, 4-10 (*Oct.*, 1952) (*in German*). Basic problems of space-flight are discussed, with the necessity for an International centre for the training of specialists in astronautics.

ASTRONOMY

(17) **Physical conditions and condition of life on other planets.** H. K. Kaiser. *Prob. Astr. Grund.*, 226-238 (*Oct.*, 1952) (*in German*). The fundamental conditions for the existence of organic life and the possibility of these conditions existing on the surface of the planets. Mars may be the home of primitive vegetation, Venus may support higher forms of life after some millions of years. All the other planets are unable to support life as we know it. (15 *refs.*)

(18) **Radio-astronomy in 1955.** M. Laffineur. *Astronomie*, **69**, 217-32 (*June*, 1955) *in French*). Comprehensive summary of modern views and techniques.

(19) **The case for the H_2O clouds on Venus**. D. H. Menzel and F. L. Whipple. *Publ. Astr. Soc. Pacif.*, **67**, 161-9 (*July*, 1955). Present authors' theory that the clouds are made of H_2O and the surface is completely covered with water.

(20) **The nature of the lunar rays.** D. Alter. *Publ. Astr. Soc. Pacif.*, **67**, 237-45 (*Aug.*, 1955). It is concluded that the rays are either dust from gases that have escaped from cracks, or a staining of the rocks by such gases.

(21) **New moons.** R. S. Richardson. *Leaflet* 316 *Astr. Soc. Pacif.* (*Sept.*, 1955). The detection and use to astronomers of faint satellites and prospects of the detection of moons of Mercury, Venus or Pluto.

(22) **The sky at 17 metres**. R. N. Bracewell. *Leaflet* 317 *Astr. Soc. Pacif.* (*Oct.*, 1955). Description of radio astronomy observations made with a wavelength of 17 metres.

(23) **Stars nearer than five parsecs.** P. van de Kamp. *Sky and Telescope*, **14**, 498-9 (*Oct.*, 1955). Description and details of the nearest stars.

BIOLOGY AND MEDICINE

(24) **The biological effects of cosmic rays. Methods and latest results.** J. Eugster. *Prob. Astr. Grund.*, 211-218 (*Oct.*, 1952) (*in German*). Reports an investigation of the biological effect of cosmic radiation by comparing results obtained in living tissue at stations on the Earth's surface, below 2,000 metres of rock, and at 30,000 metres altitude in test balloons. (15 *refs.*)

(25) **Exposure hazard from cosmic radiation at extreme altitude and in free space**. H. J. Schaefer. *Prob. Astr. Grund.*, 201-210 (*Oct.*, 1952). The extremely harmful heavy nuclei component of primary cosmic radiation is discussed, and an estimate made of the radiation exposure level in space. (10 *refs.*)

(26) **Sensory perceptions of the weightless condition.** A. E. Slater. *Prob. Astr. Grund.*, 219-225 (*Oct.*, 1952). (Also in *J. Brit. Interplanet. Soc.*, **11**, 342-348 (1952)). Description of the otolith organs of animals and accounts of some experiments made on them. The effects of weightlessness on the human operator are discussed and it is concluded that he should not be incapacitated.

(27) **The problem of radiation in space.** K. Wiese. *Prob. Astr. Grund.*, 188-200 (*Oct.*, 1952) (*in German*). Reviews the types of radiation and high energy particles to be encountered in space and some methods of protection against biological damage.

CHEMISTRY

(28) **Chemical problems of space-flight.** F. Hecht. *Prob. Astr. Grund.*, 30-39 (*Oct.*, 1952) (*in German*). Recently proposed propellants, refractory materials, metallic and non-metallic structural materials, biochemical problems, and work on the surface of planets are discussed. (30 *refs.*)

MATERIALS

(29) **Low cost materials, methods required by rockets, missiles.** C. E. Hawk. *Western Metals*, **12**, 45-8 (*Aug.*, 1954).

PHYSICS

(30) **Contrabaric dynamics for the solution of astronautical problems.** B. Heim. *Prob. Astr. Grund.*, 181-187 (*Oct.*, 1952) (*in German*). Propulsion for astronautical purposes by direct conversion of electromagnetic to kinetic energy, a method which Heim's 6-dimensional field theory indicates should be possible.

PROJECTILES

(31) **The V-2 background**. W. Dornberger. *Prob. Astr. Grund.*, 245 (*Oct.*, 1952) (*in German*). A summary of Dornberger's lecture and book *V-2, Shot into the Universe—The History of a Great Invention*, which gives a survey of its development.

(32) **"Missile off—on money!"** P. R. Heinmiller. *G.-E.Rev.*, 8-22 (*March*, 1954). Survey of guided missile research at White Sands Proving Grounds.

(33) **Defense reveals scope of missile building.** G. J. McAllister. *Aviation Wk.*, **60** (17), 12-14 (*April* 26, 1954). Review of White House Appropriations Committee testimony on vote for guided missiles.

(34) **Missile program depends on what U.S. can afford**. D. A. Anderton. *Aviation Wk.*, **60** (11), 78-80 (*March* 15, 1955). Review of present-day missiles with table of data.

(35) **Guided missiles make new demands on relays.** *Electrical Manufacturing*, **55**, 129-39 (*May*, 1955). Testing, standardisation and applications of various types of electro-mechanical relays.

(36) **Britain's guided weapon industry.** *Aeroplane*, **88**, 658-60 (*May* 20, 1955). Review of the development of British missiles.

(37) **Current progress in guided weapons.** *Aeroplane*, **88**, 661-5 (*May* 20, 1955). Review of foreign missiles—mainly American.

(38) **Guided weapons of the world.** *Aeroplane*, **88**, 666-7 (*May* 20, 1955). Tabulated data.

(39) **The dynamic motion of a missile descending through the atmosphere.** H. F. Friedrich and F. J. Dore. *J. Aero. Sci.*, **22**, 628-32, 638 (*Sept.*, 1955). A rapid yet accurate method of computation. The equations of motion are separated into a set of "static" trajectory equations (zero angle of attack) and a set of rotational equations describing oscillatory motion about the c.g. (2 *refs.*)

RADIO AND ELECTRONICS

(40) **On some high-frequency technical problems of space-flight.** R. Merten. *Prob. Astr. Grund.*, 239-244. (*Oct.*, 1952) (*in German*). The application of high-frequency radio signals to rockets and satellite vehicles. Considerations determining the arrangement and effectiveness of ground stations. (4 *refs.*)

ROCKET MOTORS

(41) **The optimum proportions of rocket components.** R. A. Cornog and F. L. van der Wal. *Prob. Astr. Grund.*, 74-88 (*Oct.*, 1952). Dimensional analysis applied to the design of fuel tanks, pumps, pipe-lines, combustion chambers and wings. (3 *refs.*)

(42) **Rotating fluid pump for large rockets.** G. E. Janzon. *Prob. Astr. Grund.*, 60-69 (*Oct.*, 1952) (*in German*). Describes a novel lightweight pump in which propellant is fed and pressurized by superheated steam.

(43) **On the question of the optimum combustion chamber pressure in rocket motors.** H. H. Kölle. *Prob. Astr. Grund.*, 47–59 (*Oct.*, 1952) (*in German*). Derives approximate relation between rocket-engine weight and exhaust velocity as a function of combustion chamber pressure, and indicates, with a worked example, how the optimum combustion chamber pressure may be determined.

(44) **Rocket apparatus.** Société d'Etude de la Propulsion par Reaction. *Brit. Pat. No.* 699,471 (*Nov.* 11, 1953). Method of tapping off and cooling gases from a main combustion chamber for driving a turbine.

(45) **Combustion equipment of rocket motors.** S. Allen and E. G. D. Andrews. *U.S. Pat. No.* 2,664,701 (*Jan.* 5, 1954). Use of pressure-responsive dump-valve on combustion chamber cooling jacket.

(46) **Means for supplying and cooling rocket-type combustion chambers.** R. H. Goddard. *U.S. Pat. No.* 2,667,740 (*Feb.* 2, 1954). Annular type injector with means for swirling propellants.

(47) **One shot rocket motor starting system.** B. N. Abramson. *U.S. Pat. No.* 2,668,412 (*Feb.* 9, 1954). Ignition system for liquid propellant motors, utilizing a third fluid injected and ignited by a pyrotechnic.

(48) **Wall structure for regeneratively cooled rocket motors.** R. B. Rossheim, D. V. Doane and C. A. Siemer. *U.S. Pat. No.* 2,669,835 (*Feb.* 23, 1954). Use of dimpling in regeneratively cooled chamber to allow use of thin walls.

(49) **Device for feeding reagents to the mixing chambers of rockets.** M. Roy. *U.S. Pat. No.* 2,671,312 (*March* 9, 1954). A combination solid and liquid-propellant rocket, some of the gas from the solid being used to pressurize the liquid tanks.

(50) **Turbojet and rocket motor combination with hot gas ignition system for nonself-reaction rocket fuels.** B. W. Bruckmann. *U.S. Pat. No.* 2,673,445 (*March* 30, 1954).

(51) **Retractable rocket igniter.** W. Riedel and L. J. Wessels. *U.S. Pat. No.* 2,674,088 (*April* 6, 1954). Igniter carried on a pivoted arm on a ground installation and inserted in the missile combustion chamber for ignition.

(52) **Combustion chamber with multiple target recesses for use in rocket apparatus.** R. H. Goddard. *U.S. Pat. No.* 2,674,848 (*April* 13, 1954).

(53) **Rocket propulsion unit without separate gas generator for turbopumps.** H. T. Holzwarth. *U.S. Pat. No.* 2,676,456 (*April* 27, 1954). Means of tapping-off gas from the main combustion chamber to drive the turbopump.

(54) **Combined rocket and jet propulsion.** F. S. Kramer. *U.S. Pat. No.* 2,676,457 (*April* 27, 1954). Method of fitting rocket unit in tail cone of a turbojet engine.

(55) **Reaction engine with automatic pressure regulation.** E. F. Chandler. *U.S. Pat. No.* 2,683,963 (*July* 20, 1954). Means of pressurizing propellant tanks from combustion chambers when several chambers are used.

(56) **Improvements in or relating to propellant supply systems for jet reaction rocket motors.** Ministry of Supply. *Brit. Pat. No.* 721,962. 4 pp. (*Jan.* 19, 1955). Starting method for turbo-pump system.

(57) **Enterprise in rocketry.** *Aeroplane*, **88**, 268-71 (*March* 4, 1955). Historical survey of rocket research and development at the De Havilland Engine Co. and description of current facilities.

(58) **G.W. propulsion system.** *Aeroplane*, **88**, 668-72 (*May* 20, 1955). Discussion of solid and liquid rocket motors, ramjets and turbojets.

(59) **Super Sprite.** *Flight*, **68**, 183-8 (*Aug.* 5, 1955). Full description and development history.

ROCKET PROPELLANTS

(60) **Cost and availability of high-energy rocket propellants.** G. V. E. Thompson. *Prob. Astr. Grund.*, 40-46 (*Oct.*, 1952). (Also in *J. Brit. Interplanet. Soc.*, **11**, 333-42 (1952)). Discussion of fuels and oxidants from the point of view of present and future availability and cost. (4 *refs.*)

(61) **Liquid and solid fuel for multistage rockets.** F. Mina. *Tec. Ital.*, **9**, 121-8 (*March*, 1954) (*in Italian*). Various types of propellants and requirements for flight beyond the atmosphere. (5 refs.)

REVIEW

Observational Astronomy for Amateurs

(By J. B. Sidgwick, F.R.A.S., Faber & Faber, Ltd. 358 pp. 50s. net)

This book is intended as a sequel to the author's *Amateur Astronomer's Handbook* and is devoted to the observational techniques employed in the various fields of amateur work.

It is divided into 19 sections dealing respectively with Solar Observation, Lunar Observation, General Notes on Planetary Observation, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, Asteroids, Zodiacal Light, Gegenschein and Zodiacal Band, Aurorae, Meteors, Comets, Variables, Binaries, Nebulae and Clusters and the final section is a copious Bibliography.

One example will indicate the scope of the various sections. Section 2—Lunar Observation—deals with: Amateur Work, Cartography, Study of the Rays, Lunar Change, Colorimetric Work, Theoretical Work, and the statistical discussion of observations, Occultations, Eclipses, Work with thermocouples, photometers and spectroscopes, Photographic work. All are dealt with in turn and are followed by Phase, Libration, with a Libration chart, Altitude, with a chart, B.A.A.H. data, N.A. data and Lunar data. The measurement of the heights of lunar mountains is not dealt with and this might be considered an omission.

The book is not a "popular" work in the usual sense and is not intended to be "read." It is a work of reference and an invaluable guide to *any* amateur, whatever branch of astronomy he may be interested in. It contains a vast amount of data collected and brought together with skill and judgment; indeed, it contains far more than the average amateur may wish to know. Nevertheless it is all there and Mr. Sidgwick is to be congratulated for having produced such a fine compendium. Used by itself it is a "must" for all serious workers; used together with the *Amateur Astronomer's Handbook* the two books form a single unit of great value.

Errors are conspicuous by their absence, any desired topic can be found with the aid of the Index. The only regret is the somewhat high price which places it out of the reach of many amateur observers. The book can be highly commended and should be in the possession of all lovers of the heavens.

H. P. WILKINS.

INTERPLANETARY FILM STRIP

The Society has prepared, for the benefit of lecturers, a 35 mm. film strip containing 50 pictures showing modern rockets, orbital satellites, spacesuits, spaceship designs, and astronomical subjects. This strip will be invaluable not only to speakers wishing to address organisations of any type, but also to those wishing to have a private collection of rocket and space-flight pictures. If a projector is not available, the strip can of course be examined by one of the 35 mm. transparency viewers obtainable at any photographer's.

The cost is 10/- per strip, post free, which works out at the modest sum of 2½d. a picture. Orders should be sent to the Secretary at 12, Bessborough Gardens, S.W.1.

CORRESPONDENCE

Electrostatic Generator

SIR,

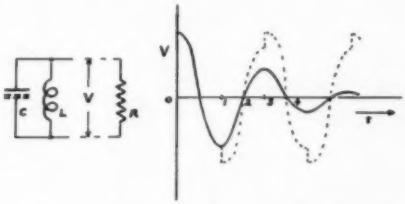
I was most interested to see Dr. Brosan's article in the Sept.-Oct. *Journal* describing an electrostatic generator for use as a power supply "in vacuo."

This brings to mind a machine built in Russia some years before the war, reference to which may be found in *J. Tech. Phys., U.S.S.R.*, **3**, 1141 (1933); **4**, No. 1, 5 (1934), by Mandelstam and Papalexi.

The paper deals with the parametric excitation of oscillations in a tuned circuit, the capacitive element of which is varied in value at a frequency twice that of the circuits' natural resonance.

The action of the generator can be explained simply in terms of energy impulses and the logarithmic decrement of the circuit.

Consider a circuit consisting of the parallel connection of C, L and R (which latter constitutes the Load + Losses).



A charge placed on the condenser at $t = o$ will give rise to a sinusoidally varying output voltage of decrement $e - \frac{t}{2cR}$. If, however, at $t = 1$, the plates of the condenser are pulled apart, the voltage between them increases. The plates of the condenser are restored to their original position at $t = 2$ when there is no voltage between them and therefore no work is required or subtracted from the circuit. At $t = 3$ they are pulled apart again and so on, so that the initial peak voltage is maintained.

Substituting a rotary variable capacitor for the "electrophorus" described, gives us a generator, prototypes of which are said to have produced usable power at a high voltage and frequency.

Physically the generator consists of a long, many bladed rotor—similar in appearance to a turbine rotor, difficulty being encountered with blade clearance. It is run partially evacuated (mainly, I believe, to reduce windage), is virtually self-sustaining with regard to excitation and the efficiency is high.

In these and other respects it would appear to have practical implications similar to those of the generator described by Dr. Brosan.

Dalkeith, Midlothian. E. H. BALLANTYNE, A.M.I.E.E.

Cosmic Rays

SIR,

A small point has occurred to me concerning interplanetary orbits outside the plane of the ecliptic which I have not seen discussed before.

While no great danger of radiation poisoning is anticipated from cosmic rays just outside our own atmosphere, we know that the most likely particle to cause concern is the slow moving heavy primary. These highly charged nuclei are severely affected by the Earth's magnetic field and are deflected away from the geomagnetic equator. The overall cosmic ray intensity then increases towards the poles and theoretically should reach a peak at that point. However studies with "Rockoons," by the U.S. Navy have shown that it levels off about latitude 55°.[1]

One explanation might be that the magnetic field of the Sun may be strong enough partially to shield the planets even as far out as Earth. The slower heavier particles, which were expected to be found at the poles, but were not, may have been diverted by the solar field away from the ecliptic, presuming that this is parallel or almost parallel to the Sun's geomagnetic equator.

This would mean that as one gets further from the ecliptic the radiation intensity from cosmic rays, particularly the dangerous large nuclei, will rise—possibly beyond acceptable levels.

S/Ldr. T. F. SANDEMAN, M.B., Ch.B.

R.A.A.F., Uranquinty,
N.S.W., Australia.

REFERENCE

(1) H. J. Schaefer: "Theory of the Protection of Man in the Region of the Primary Cosmic Radiation," *Journal of Aviation Medicine*, Vol. 25, p. 338, 1954.

Life on Mars

SIR,

It would be interesting to know if biologists and physiologists agree with the comments of Mr. Moore on the beginnings of animal life (p. 81 of the March-April, 1955, *Journal*).

A living membrane of animal cells can secrete substances from a low concentration on one side to a high concentration on the other side in defiance of physics and osmosis.

If the free oxygen in our sea water had been, say, only one-tenth of what it really is, the fish could have had more gill area moving faster.

With less oxygen in the air, the amphibians could have left the water by having larger respiratory skins, with larger blood vessels, and their lungs would have evolved to suit a low oxygen atmosphere.

Intelligence helps survival, though the history of the dinosaurs and mammals shows how very long it can take to get far. The human brain is a unique product of tears, sweat, love, hate, heat, cold, desert, ice, starvation, disease, defencelessness, and necessity; there may be plenty of these things on Mars.

Salisbury, Rhodesia. C. M. HEANLEY, M.B.

ELEVENTH ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the 11th ANNUAL GENERAL MEETING of the BRITISH INTERPLANETARY SOCIETY will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on Saturday, **the 21st day of April, 1956,** at 6 o'clock in the evening precisely, for the transaction of the business specified in the Agenda below.

AGENDA

1. Chairman's Address.
2. To receive the annual statement of accounts and balance sheet for the year ended September 30, 1955, and the auditor's report thereon.
3. To elect four Members of the Council of the Society. In accordance with the provisions of Article 15, the following four Members of the Council will retire at that meeting, and, with the exception of Mr. D. F. Lawden, offer themselves for re-election:

   D. Hurden. D. F. Lawden. A. E. Slater. R. A. Smith.

   Nominations for Messrs. W. N. Near, J. A. Moyse and E. T. B. Smith, have so far been received. As the number of nominations exceeds the number of vacancies, election will be by postal ballot, and the necessary ballot papers will be issued in due course.
4. To consider, and if thought fit, to pass the following as **Special Resolutions** of the Society:

   (*a*) That Article 5 (*c*) be amended to read 5 (*d*) and that the original Article 5 (*d*) be deleted.

   (*b*) That a new Article 5 (*c*) be inserted, reading as follows:—
   SENIOR MEMBERS. This shall be open to those Members of the Society who shall have been members continuously for a period of not less than 7 years, and who shall pay an annual subscription of £2 12s. 6d.

   (*c*) That a new Article 5 (*e*) be inserted, reading as follows:—
   "CORPORATE MEMBERS, the terms and conditions of membership concerning which shall be prescribed by the Council in Bye Law."

   (*d*) That a new Article 5 (*f*) be inserted, reading as follows:—
   "Notwithstanding anything in this Article, the Council may, from time to time and with the sanction by ordinary resolution of the Society in General Meeting, exercise such discretionary power as they may think fit in connection with the amount of the fees payable by members, provided that in no case may any person be a member of the Society on payment of a subscription of less than £1 1s. 0d. per annum."
5. Any other business.

By order of the Council,

L. J. CARTER,
Secretary.

A member who cannot be personally present at the meeting may appoint by proxy some other person (who must be a member of the Society) to attend and vote on his behalf, subject, however, to the limitation that a proxy cannot vote except on a poll.

ADDRESSES DELIVERED TO THE LONDON MEETINGS OF THE SOCIETY DURING THE SESSION 1954-1955

Saturday, October 16, 1954.
21st Anniversary Celebrations, at the Waldorf Hotel.

Saturday, November 6, 1954.
"Medical Aspects of Flight above the Atmosphere," by Col. P. A. Campbell, U.S.A.F.
This lecture was concerned with the basic biological problems which will be encountered in space-flight and some of the solutions and partial solutions that exist to-day.

Saturday, December 4, 1954.
Annual General Meeting.

Saturday, December 11, 1954.
"The Planet Mars," by P. Moore, F.R.A.S.
A description of recent investigations of Martian phenomena, with special reference to the close approach of 1954 and to the even closer approach which will occur in 1956.

Saturday, January 8, 1955.
(*a*) "Using Hydrogen Peroxide," by A. V. Cleaver, F.R.Ae.S.
The handling, storage and other problems encountered in the use of concentrated H_2O_2 as a rocket propellant.
(*b*) "Liquid Oxygen as a Rocket Propellant," by S. Allen, M.I.Mech.E., A.F.R.Ae.S.
The production and storage of liquid oxygen, and some of the problems involved in its use in rocket engines for inhabited vehicles.

Saturday, February 5, 1955.
"The Development of the 'Snarler' Rocket Motor," by D. Hurden, B.A., Grad.I.Mech.E.
An account of some of the problems encountered in the development of this engine and the methods used to overcome them.

Saturday, March 5, 1955.
"The Radio Exploration of Space," by R. C. Jennison, B.Sc.
An account of the cosmical revelations provided by the new science of radio astronomy, with special reference to recent discoveries affecting radio communication within the solar system, meteoric activity, catastrophies in outer space, and the birth of galaxies.

Saturday, April 2, 1955.
"Problems of Heat Transfer in Rocket Motors," by H. Ziebland, Dip.Ing.
This paper dealt with the peculiarities of convective and radiative heat transfer from high pressure and temperature combustion gases and heat transfer from receiving walls to coolant with reference to various cooling techniques.

Saturday, May 14, 1955.
Short Paper Evening. A number of short ten-minute papers on various aspects of space-flight were read and discussed.

SYLLABUS OF ACTIVITIES OF THE MIDLANDS BRANCH DURING THE SESSION 1954-1955

Saturday, October 9, 1954.
"The Planet Mars," by P. Moore, F.R.A.S.
A description of the planet in the light of our present knowledge.

Saturday, October 23, 1954.
21st Anniversary Celebration Dinner and Exhibition.

Saturday, November 6, 1954.
"Radar and Space Travel," by R. A. Lampitt, A.M.I.Brit.R.E.
A description of radar and allied electronic equipment and possible applications to space-flight.

Saturday, December 11, 1954.
"Extra-Terrestrial Observations," by C. A. Cross, M.A.
The most suitable location and possible structure of an astronomical observatory outside the Earth's atmosphere are considered, and some novel methods for the construction of a very large parabolic mirror under free-fall conditions explored.

Saturday, January 8, 1955.
"Spectroscopy in Astronautics," by W. H. T. Davison, M.A.
A discussion of some applications of spectroscopy to astronautics.

Saturday, February 5, 1955.
"Civil Engineering on Other Worlds," by M. S. Wright, B.Eng., read by D. A. Parish.
An outline of the problems likely to be met by colonists on other planets in the construction of bases there.

Saturday, March 5, 1955.
"The Path to Space Travel," by K. W. Gatland.
An outline of progress in guided missiles, high altitude research, supersonic aerodynamics and aero-medical research.

Saturday, April 2, 1955.
Short Paper Evening. The following short papers were given:
(*a*) "How the Metallurgist can help the Rocket Engineer," by P. J. Allender, Ph.D., B.Sc.
(*b*) "Electronics and Space-Flight," by J. C. Mawer.
(*c*) "Tubes in Astronautics," by R. B. Beard, Grad.I.Mech.E.

Saturday, April 30, 1955.
Branch Annual Business Meeting.

SYLLABUS OF ACTIVITIES OF THE PROVISIONAL SCOTTISH BRANCH DURING THE SESSION 1954-1955

Tuesday, October 26, 1954 (*at Glasgow*).
"Film Show."
The films *The Viking Rocket, High Altitude Research* and *Rocket Assembling and Launching* were shown, and Dr. M. W. Ovenden, the Branch Chairman, gave a short address at the conclusion of the proceedings.

Friday, October 29, 1954 (*at Edinburgh*).
"Film Show."
A repeat of the films shown in Glasgow the previous Tuesday.

Friday, November 26, 1954 (*at Edinburgh*).
"The Rocket as a Scientific Instrument," by M. W. Ovenden, Ph.D.
A review of developments in upper atmosphere sounding by high altitude rockets during the past ten years, with a summary of the results obtained and a forecast of probable future developments.

Tuesday, November 30, 1954 (*at Glasgow*).
"The Rocket as a Scientific Instrument," by M. W. Ovenden, Ph.D.

Tuesday, January 25, 1955 (*at Glasgow*).
"Brains Trust."
A "Trust" of three members under the chairmanship of Mr. J. R. R. Burton answered questions on astronautics raised by members of the audience.

Friday, January 28, 1955 (*at Edinburgh*).
"Astronautical Medicine," by J. C. Guignard.
A survey of present-day medical knowledge obtained from experience of "space equivalent" conditions, with an outline of probable future problems in this field.

Tuesday, February 22, 1955 (*at Glasgow*).
"Some Physical Effects of Space Travel," by J. Lindsay, M.A.
The effects of acceleration on the human body, no gravity effects, reaction time to high speed travel (particularly vision) and possible dangers from radiation.

Friday, February 25, 1955 (*at Edinburgh*).
"Brains Trust."
A "Trust" of three members sitting under the chairmanship of Mr. P. S. Reid answered questions from the audience.

Friday, March 25, 1955 (*at Edinburgh*).
"Pilotage and Navigation of the Interplanetary Vehicle," by P. H. Tanner, B.Sc.
The requirements for safe navigation of an interplanetary vehicle, with an outline of some of the methods by which they may be met.

Tuesday, March 29, 1955 (*at Glasgow*).
"Pilotage and Navigation of the Interplanetary Vehicle," by P. H. Tanner, B.Sc.

Tuesday, April 26, 1955 (*at Glasgow*).
"Faster than Sound."
After a showing of the film *Faster than Sound* a short talk on the problem of supersonic flight was given by Mr. P. H. Tanner.
The Annual General Meeting was held at the conclusion of the proceedings.

SYLLABUS OF ACTIVITIES OF THE NORTH-WESTERN BRANCH DURING THE SESSION 1954-1955

Saturday, October 9, 1954.
21st Anniversary Dinner was held at the New Millgate Hotel, Manchester.
The guest of honour was Mr. P. E. Cleator, Founder of the Society.

Saturday, November 20, 1954.
"Extra-Terrestrial Observatories," by C. A. Cross, M.A.
The most suitable location and possible structure of an astronomical observatory outside the Earth's atmosphere were considered, and some novel methods for the construction of a very large parabolic mirror under free-fall conditions were explored.

Saturday, December 18, 1954.
"Débris in Space," by E. Burgess, F.R.A.S.
An account of possible hazards to space-flight from interplanetary matter, meteors, solar corona, zodiacal light, cosmic rays, etc., with a discussion of how probe rockets can make preliminary surveys.

Saturday, January 15, 1955.
"High-speed Flight," by R. J. Boor, A.M.C.T.
An outline of the problems facing the designer of high Mach number and high altitude aircraft and missiles. Compressibility effects on stability and control, Mach number and the drag rise, the nature of wave drag and an introduction to supersonics.

Saturday, February 19, 1955.
An astronomical symposium consisting of the following papers:
"Drawing the Solar System to Scale," by P. L. Sowerby, A.M.C.T.
"Suitable Locations for Leaving the Earth," by F. B. Cowell.
"Odd Telescopes," by P. Y. Millins.
"Lunar Valleys," by G. Fielder, B.Sc.

Saturday, March 19, 1955.
"Rocket Engineering," by Prof. A. D. Baxter, M.Eng., M.I.Mech.E., F.R.Ae.S.
A lecture discussing the principles of rocket propulsion and engineering showing how considerable improvements are possible and indicating the lines of development which might yield profitable results.

Saturday, April 16, 1955.
A film show at which the film *Destination Moon* was shown to members.

Saturday, April 23, 1955.
Branch Annual Business Meeting.

SYLLABUS OF ACTIVITIES OF THE PROVISIONAL SOUTHERN BRANCH DURING THE SESSION 1954-1955

Saturday, March 19, 1955.
"Film Show," followed by a talk by Mr. L. J. Carter, the Society's Secretary, on the "History and Aims of the Society."
At the conclusion of this talk, a Provisional Committee was elected to arrange a future Programme.

Saturday, May 7, 1955.
The film *Rocket Instrumentation* was shown, followed by two short talks:
(*a*) "Space Travel," by D. H. Penney.
(*b*) "Rockets," by R. Lennox Napier.

SYLLABUS OF ACTIVITIES OF THE PROVISIONAL YORKSHIRE BRANCH DURING THE SESSION 1954-1955

Saturday, October 20, 1954 (*at Leeds*).
21st Anniversary Dinner.

Saturday, November 20, 1954 (*at Leeds*).
"High Altitude Research," by E. Burgess, F.R.A.S.
A survey of rocket instrumentation and methods of obtaining data on high altitude conditions.

Friday, November 26, 1954 (*at Harrogate*).
"The Facts about Space Flight," by Lieut.-Col. G. E. B. Stephenson, M. S. Wright, B.Eng., and L. S. Strickson.
An elementary survey covering Rockets, The Planets and Artificial Satellites.

Saturday, December 18, 1954 (*at Sheffield*).
"Living in Space," by M. S. Wright, B.Eng.
An outline of conditions in space and man's ability to adapt himself with the aid of suitable engineering projects.

Friday, January 14, 1955 (*at Harrogate*).
"The Moon," by G. Fielder, B.Sc.
An account of methods used to obtain data on the Moon.

Friday, February 18, 1955 (*at Leeds*).
"Film Show."
(*a*) *Rocket Instrumentation.*
(*b*) *The German A-4 Rocket.*

Saturday, February 19, 1955 (*at Sheffield*).
Repeat of Film Show, previously screened at Leeds.

Friday, February 25, 1955 (*at Harrogate*).
"The Solar System," by Lieut.-Col. G. E. B. Stephenson.
A description of the physical conditions to be found on the planets.

Saturday, March 19, 1955 (*at Sheffield*).
"The Moon," by M. C. Metcalfe.
A description of the characteristics of the Moon's surface.

Thursday, March 24, 1955 (*at York*).
"An Introduction to Astronautics," by L. S. Strickson.
An outline of the elementary principles of space-flight.

Thursday, April 21, 1955 (*at York*).
"The Moon," by M. C. Metcalfe.
A talk illustrated with slides showing some of the main characteristics of the lunar surface.

Saturday, April 19, 1955 (*at Leeds*).
(*a*) "A History of Rocketry," by L. S. Strickson.
A review of the development of the rocket from earliest times.
(*b*) Annual Branch Business Meeting.

JOURNAL BINDINGS

Arrangements have been made with our printers for binding the *Journal* at a cost of 9s. 6d. (post free). The volumes are in dark green, with gilt lettering. Earlier volumes may also be bound in the same manner.

All you need do to obtain your *Journal* in this smart and convenient form is to send the six issues, plus *Index* sheets (to be issued early in 1956) to W. Heffer & Sons, Hills Road, Cambridge, with the necessary 9s. 6d. Please do not send them to the Society!

BIS BADGE

The Society has available a badge, the design of which was finally selected from a large number of drawings submitted by members.

The badge is neat and simple. It is abstract in design, and not meant to indicate any projected design for a future spaceship.

A reproduction of the badge (actual size) is shown, and is available at 4/6, post free.

When placing orders, please state whether a stud or brooch type badge is desired.

The British Interplanetary Society

Limited (by Guarantee)

INCOME AND EXPENDITURE ACCOUNT for the year ended September 30th, 1955.

1954	*Expenditure.*	£ s. d.	£ s. d.
£			
	To Office and Management Expenses—		
233	Rent, Light, Heat, Cleaning and Insurance	235 2 6	
416	Salaries and National Insurance	533 8 4	
272	Printing and Stationery ..	281 17 6	
245	Postage, Telegrams and Telephone	204 8 5	
94	Publicity and Advertising ..	102 14 6	
182	Travelling and Entertaining Expenses	203 8 0	
116	Sundry Expenses	122 1 6	
			1,683 0 9
1,558			
2,168	» **Publications**		2,630 5 3
293	» **Expenses of Meetings** ..		335 7 2
381	» **21st Anniversary Celebrations**		76 18 11
	» **International Astronautical Federation—**		
159	Contribution and Expenses ..		194 14 9
21	**Income Tax**		36 11 0
	» **Depreciation of—**		
95	Furniture and Equipment ..	96 12 0	
223	Library Expenses	88 12 6	
			185 4 6
300	» **Transfer to General Reserve**		500 0 0
	» **Excess of Income over Expenditure** for year carried		
639	to Accumulated Fund ..		471 7 5
5,837			6,113 9 9

1954	*Income.*	£ s. d.	£ s. d.
£			
	By Membership Subscriptions		
4,922	**and Entrance Fees** ..		5,023 4 9
297	» **Donations**		325 4 0
390	» **Library Subscriptions and Sale of Journals**		478 0 8
	» **Income from Investments—**		
18	3½% Defence Bonds	35 0 0	
28	Deposit Account Interest ..	42 2 5	
			77 2 5
182	» **Sundry Receipts**		209 17 11
5,837			6,113 9 9

BALANCE SHEET as at September 30th, 1955.

BALANCE SHEET as at September 30th, 1955.

1954 £	Capital and Reserves.	£ s. d.	£ s. d.
	Accumulated Fund—		
1,459	Balance at September 30, 1954	2,098 10 9	
639	*Add* Excess of Income over Expenditure for the year..	471 7 5	
			2,569 18 2
2,098			
	Compounded Subscriptions Reserve Account		1,361 0 0
1,245	**General Reserve**		1,500 0 0
1,000	**Income Tax Reserve**		57 17 0
29	**21st Anniversary Celebrations**		– – –
350			
4,722	Total of Capital and Reserves		5,488 15 2
	Current Liabilities.		
163	**Subscriptions Paid in Advance**	321 5 9	
93	**Sundry Creditors**	149 10 3	
			470 16 0
	Certified to be a true copy— L. R. SHEPHERD, G. V. E. THOMPSON } *Members of the Council.* L. J. CARTER, *Secretary.*		
4,978			5,959 11 2

1954 £	Fixed Assets.	£ s. d.	£ s. d.
	Furniture and Equipment—		
1,049	At Cost	1,355 17 0	
419	*Less* Depreciation	515 17 0	
			840 0 0
630			
	Library—		
423	At Cost	422 18 2	
323	*Less* Depreciation	322 18 2	
			100 0 0
100			
	Investments—		
2,000	Establishment Fund Deposit Account	3,000 0 0	
1,000	3½% Defence Bonds (P.O. Issue)	1,000 0 0	
3,000			4,000 0 0
3,730	Total of Fixed Assets ..		4,940 0 0
	Current Assets.		
—	**Stock of Badges**	50 0 0	
24	**Sundry Debtors**	46 6 3	
53	**Payments made in Advance** ..	53 5 0	
1,154	**Cash at Bank**	846 1 2	
17	**Cash in Hand**	23 18 9	
			1,019 11 2
4,978			5,959 11 2

REPORT OF THE AUDITOR TO THE MEMBERS OF THE BRITISH INTERPLANETARY SOCIETY

I have obtained all the information and explanations which to the best of my knowledge and belief were necessary for the purposes of my audit. In my opinion proper books of account have been kept by the Society so far as appears from my examination of those books. I have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account. In my opinion and to the best of my information and according to the explanations given to me, the said accounts give the information required by the Companies Act, 1948, in the manner so required, and the Balance Sheet gives a true and fair view of the state of the Society's affairs as at September 30, 1955, and the Income and Expenditure Account gives a true and fair view of the surplus of income over expenditure for the year ended on that date.

35, Brian Avenue,
Sanderstead, Surrey.

1st *January*, 1956.

T. W. WOODS,
Incorporated Accountant.

CHAIRMAN'S ADDRESS

(For the convenience of members unable to be present, the Chairman's speech is reproduced below.)

Gentlemen,

The period from October 1, 1954, to September 30, 1955, which I have to review, has been one of particular significance in the field of astronautics. For more than a decade we have heard the disconnected chords as the instruments were tuned; now the conductor has raised his baton, the overture has begun, and, in two or perhaps three years, the curtain will be raised upon the greatest drama in history—the conquest of space.

The development that was revealed to the world at the end of July can be no surprise to the members of this Society, who must have been fully aware of the inevitability of satellite vehicles and space-flight. In fact, it will be recalled that as long ago as 1948 an official pronouncement on the so-called Earth–Satellite Vehicle was made in the United States. However, that was only a rather general statement of interest in the possibilities of such a device, whereas the present announcement has been specific in character and mentioned target dates, which have surprised many by their proximity. It appears from information that has been released recently, that the satellite project "Vanguard" is to be carried out under the direction of a U.S. Navy department and that the three-stage rockets, which will bear the tiny moonlets into their orbits, are to be constructed by the Glenn-Martin Co., who were responsible for the Viking upper-atmosphere research rockets. General Electric are to make the engines for the largest stages of these vehicles. It is understood that Dr. Milton W. Rosen is to be technical director.

It may be assumed that the United States will not be alone in its venture into the realms of astronautics. The U.S.S.R. is known to be well-advanced in the field of rocket propulsion, and there have been semi-official statements concerning Soviet intentions in the development of satellite vehicles.

No less important in their implications to the ultimate achievement of space-flight have been the recent revelations concerning the so-called Inter-continental Ballistic Missiles. The U.S. project "Atlas," of which some details were given in the November–December *Journal* (1955), may well be the forerunner of bigger and better satellite vehicles. Military rockets are inevitably one jump ahead of those which are used for purely scientific purposes, and we may assume that a missile such as Atlas will be more advanced even than the Vanguard vehicles.

On the home front some information on British high altitude rockets for use during the International Geophysical year have been revealed. One can say, quite fairly, that they are almost ten years late in arriving upon the scene, and express the hope that the first U.K. satellite vehicle will not be delayed by a similar period. I consider that the B.I.S. continues to have a useful role to fulfil in keeping attention focused upon the need for space vehicles and their scientific importance.

Turning to domestic matters, the current year began with a month of celebrations in connection with the B.I.S. 21st Anniversary (October, 1954),

and dinners were held in London and the Branches. The London affair was a particularly successful venture, and in response to many requests we are planning to hold an Annual Dinner in future. The value of these occasions as a means of bringing members together cannot be overestimated. In this connection we have held, also, informal meetings outside the normal London lecture programme, following upon requests made at the 1954 Annual General Meeting. These were not very well attended, but we shall continue to hold such gatherings in 1956.

Membership

Of the state of the B.I.S. during the past session, it may be said that the intake of new members has continued to fall compared with the boom years of the early 1950's. The total membership at September 30, 1955, was 2,717, consisting of 697 Fellows and 2,020 members, an increase of 129 over the total for the previous year. The decline in intake is under constant review by the Council and counter-measures are being considered. The trend is rather surprising in so far as the general interest in astronautics, as revealed by requests for lectures, articles and material for books, etc., has shown a marked increase of late. Societies in several other countries have noted a similar trend in membership statistics, one or two of them having to record an actual decline. It is possible that the various societies are actually suffering as a result of the increase in official government-sponsored activities in near-astronautical fields. Many would-be members may feel that the Interplanetary societies are rather divorced from the real technical advances that are being made, and that they have no real contribution to make as a consequence. Nothing could be further from the truth. Astronautical societies through the medium of their publications, lecture meetings, and International Congresses, have put forward many of the original ideas in this field, and they will continue to do so in the future. Dr. Rosen, in a recent article,* emphasizes the important rôle played by the societies in this respect. The B.I.S. Council is unanimous in its conclusion that one of the best ways in which this Society can further the conquest of space lies in our active pursuit of a policy of soliciting original technical papers.

Spaceflight

An important new development in the policy of the Society has been the decision to start a new publication. This will be a journal on the popular level, the object of which will be to present information and news about astronautics in a manner that will make it understandable to the layman. It has been decided that the new journal will be called *Spaceflight*, and we hope to produce two issues during 1956. This will be the first step towards satisfying the past criticisms of our publication policy, which has taken two diametrically opposite stands, claiming, on the one hand that our *Journal* was too technical, and on the other that it was not technical enough. Eventually, we hope to have a purely technical *Journal* to satisfy the second school of thought, and on the other hand the non-technical *Spaceflight* to satisfy our first group of

* "Jet Propulsion," **25**, 623 (Nov., 1955).

critics. I need hardly say, however, that this new venture will entail a lot of extra work, and it will not be fair if this has to fall on the backs of those who are already bearing the brunt of B.I.S. affairs. As always, our main need will be for good original papers, review articles and other publishable material, both in the popular and technical vein. I would like to repeat and emphasize the appeal which I made to you in my last address for help in this direction.

Other Publications

Publication activities in the astronautics field is booming, with more and more publishing houses expressing an interest in the matter. One outcome of this is a proposal to publish a volume of B.I.S. Collected Papers under the Editorship of L. J. Carter, which will contain a selection of suitable articles from post-war journals. Another venture having Council approval, is an *Astronautics Handbook*, to be edited by J. Humphries and E. T. B. Smith, which will be a compilation of the best available technical data relating to space-flight.

It is appropriate to mention in connection with publications, that three issues of the I.A.F.'s *Astronautica Acta* have now appeared. The circulation of this journal had reached a figure of approximately 250 by August. It is disappointing to note, however, that the response from the U.K. has been rather small. Perhaps this is a consequence of the fact that we are already fairly well served by the B.I.S. *Journal* and the A.R.S. *Jet Propulsion*. However, it is hoped that more B.I.S. members will take up subscriptions to this important publication.

Special Business

During the past Session the Council has considered modifications to the constitution of the Society in connection with the grades of membership and has concluded that there exists a need for two new grades of membership, namely:—

(*a*) Corporate Membership.

(*b*) Senior Membership.

The first of these would enable industrial firms and professional bodies interested in Astronautics to join the B.I.S. on a corporate basis. This form of membership is quite common in professional societies, the A.R.S. has such an arrangement and recently the I.A.F. adopted a resolution to introduce Institutional membership. The Council considers that the introduction of this new grade of membership will be beneficial in spreading information regarding the B.I.S. in important industrial and professional quarters.

The idea underlying the introduction of a Senior Membership grade, is that there should be greater degree of incentive and encouragement for the non-professional members of our Society. This will become increasingly important if we wish to make the requirements for Fellowship more stringent. Senior Membership is intended to be available only to members who have been in the B.I.S. for a minimum of seven years, thereby establishing their loyalty to the Society and its aims. The grade of Senior Membership would carry all the privileges of Fellowship and the subscription rate is to be the same.

Finally, the Council has decided that the B.I.S. should fall in line with other professional societies, in making a reduction in the fees paid by students of Universities and Technical Colleges. The reduction would be available to both undergraduate and post-graduate students subject, however, to a time-limit of three years over which this special privilege could be enjoyed. Effect has been given to this proposal by the inclusion of a new Article, 5 (*f*), which gives the Council a discretionary power to amend the fees payable in special cases, subject to the approval of the Society in General Meeting and with the proviso that fees shall in no case be less than £1 1s. 0d. per annum. Following the acceptance of this proposal, the Council will submit to the meeting, for approval, several ordinary resolutions which set out their proposed regulations governing the fees payable by students.

These new proposals of the Council, if adopted, necessitate amendments to the constitution of the Society, and accordingly the Council will place before this meeting Special Resolutions calling for the necessary amendments.

Meetings

During the year the Society held a total of 51 meetings in London and the Branches, and, in addition to these, a number of informal meetings were also held. Unfortunately, the informal meetings held in London were rather poorly attended, but nevertheless your Council feel that they meet a very real need and are potentially of great value. Accordingly, they have planned an extension of these activities during the coming year, and I very much hope that many of our members will come along to make these meetings a success.

The 10th Annual General Meeting of the Society was duly held on May 14, 1955, for the reasons which were outlined in my address last year. At that meeting the retiring Members of the Council were re-elected and I was again subsequently elected Chairman. The present term, however, marks my last year of office, as our regulations require that no person may be Chairman for more than three consecutive years, and I should like to thank the other Members of the Council, who have so consistently and loyally helped me during my term of office.

Besides our own meetings, the Society often receives requests for lecturers from other organizations. Many of these can be accepted, but there is a wide unsatisfied demand from youth clubs and social organizations of all sorts in the London area, and any suitably qualified Fellows who are willing to assist in such work are invited to give their names to the B.I.S. Secretary. The number of such outside meetings addressed by members of the Society each year is not known with certainty, but it probably totals between two and three hundred lectures each year.

I should like to mention here that the Society has available a set of lecture notes which can be obtained free of charge by any member on application to the Secretary. These usually prove very helpful in planning general lectures and are often used in conjunction with the Society's Film Strip, sales of which have now exceeded 350.

Branch Matters

A high level of activity has been maintained in the Branches during the session under review. The lecture programmes in most of the Branches are now on a par with those in the Headquarters region. I am able to record that the Western Branch is now established on a recognised basis, following a resolution adopted by the Council on February 5, 1955, and I feel sure that you will join me in wishing it every success in the future.

The Council, once again, extends its thanks to the officers and committees of the Branches for their continued service to the Society. While recording our satisfaction at the Branch activities, I would like to add a plea, on behalf of the Publications Committee, however, for more publishable material. We would like to receive more lectures and articles from the Branches suitable for inclusion in the *Journal* and *Spaceflight*. This will not only add to the prestige of the Branches but also greatly help the editors of these publications.

Accounts

The accounts for the financial year ended September 30, 1955, appear on pages 64–65, and disclose a further improvement in our position. During the year we have been able to transfer £500 to our General Reserve Account, which now stands at £1,500. These reserves are very necessary, as, although our present financial position is satisfactory, we will shortly have to face a number of increases in expenditure. The recent increase in postage rates hits us severely and will cost several hundred pounds in the forthcoming year. Printing costs generally also continue to rise, and, in addition, we urgently need additional help to cope with our ever-increasing volume of correspondence. Last year a total of over 13,000 items of correspondence were issued from H.Q., and present indications are that this will be exceeded by a considerable margin during the coming year.

A further problem arises in connection with our premises, which are held on a very short lease and for a relatively small rental. When this lease expires, we shall undoubtedly be faced with a sharp increase in rent, and the fact that we shall also be requiring additional accommodation then still further aggravates the problem.

The cost of publications this year shows a sharp increase and this is likely to be increased still further next year when *Spaceflight* is produced, for the cost of this new publication will be much more per issue than for our present *Journal*, owing to the fact that it is planned to have a larger format and many more illustrations. Some rearrangement of our publications policy will arise from this, and this will be announced in the *Journal* in due course.

Reserves from Compounded Subscriptions show a further small rise. These funds do very much to add financial stability to the Society, and I should like to bring it to the attention of those members who could take advantage of the scheme as a means of assisting both the Society and themselves.

A further very useful way of helping our administration at a very busy time is the practice of paying subscriptions by bankers order. The saving in clerical labour is substantial, and members having bank accounts can well find the Secretary only too willing to provide Bankers Order forms for this purpose.

Secretarial Administration

A few final remarks may be devoted to the direction and administration of the B.I.S. The Council has recently reached the conclusion that the administration of the Society should be strengthened by the appointment of an Assistant Secretary, who will be able to relieve our hard-worked Secretary of many of his present tasks. The possibility of appointing a Technical Secretary is also under review, but no decision has been made yet.

Council

During the year the Council has met 11 times to conduct the affairs of the Society, and it is appropriate to note, in connection with the government of the Society, that the Council will shortly be losing one of its most active members when Mr. Derek Lawden departs to take up the Chair of Mathematics at Christchurch, New Zealand. No member of this Society has contributed more to the B.I.S. *Journal* than Mr. Lawden has done, and, in addition, he has served on the Publications Committee during the past two years. We wish him every success in his new post and express the hope that distance will not unduly attenuate the stream of his mathematical papers on space-flight, which have become an essential part of the literature of astronautics in recent years.

L. R. SHEPHERD,
Chairman of the Council.

List of Donations

Donations totalling £324 11s. 3d. were received from 515 members during the year and are gratefully acknowledged.

A list of the donors of amounts of 10s. and over is printed below.

Adams, H. E.
Aldrich, F. N.
Allery, P. J.
Andrew, E. J.
Arthur, K. B.
Bachrach, A. J.
Bailey, D. A.
Bailey, F. R.
Bancroft, J. G.
Barber, D. M.
Bardens, A. T.
Barnett, P. A.
Barrett, A. M.
Barrett, J. W. S.
Bates, B. R. E.
Bates, R. D.
Becker, D. J.
Best, L.
Bevelheimer, B. L.
Black, A. P.
Blair, H. O.
Blakeley, G.
Blenkinsop, H. G.
Bonestell, C.
Boxall, V. S.
Bridge, W. E.
Brown, A. S.
Brown, K. L.
Bruski, E.
Burbage, J.
Butler, J. J.
Byard-Jones, M. J.
Bygroves, J. J.
Byrne, J. E. G.
Byron-Scott, R. A. D.
Camp, J. R.
Campbell, H. A.
Camplin, A. B.
Capaldi, G.
Carter, C. V.
Caulkett, S. G.
Chandler, P. J. G.
Chester, J. M.
Chrestenson, D. J.
Clark-Gibbs, D.
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Clegg, R. W.
Coldrick, D.
Cooke, W. D.
Costar, W. D.
Cotton, J. A. W.
Culme-Seymour, M. C.
Curran, E. T.
Cutler, D.
Davidson-Houston, J. H.
Davies, D. G.
Davies, G. O.

Day, V. A.
Deane, I. J.
Dennis, T. H.
Dewar Simon, C.
Dobson, W.
Douglas, R. N.
Dudley, I. A. J.
Duke, S. B.
Durant, F. C.
Duval, B.
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Ellis, C. A. P.
English, P. T.
Ettridge, F. A.
Evans, A.
Falkner, H. E.
Fanthorpe, R. L.
Farnon, R. J.
Fellin, C.
Fiala, D. F.
Finlay, W. H.
Fitch, J.
FitzSimmons, R. A.
Flint, W. O. L.
Fraser, K. J.
Freeman, D. A.
Freerton, T. C.
Furness, K.
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Glynn B.
Gordon, J. H.
Green, A. P.
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Hales, O. K.
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Hall, B. R.
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Hammerton-Fraser, A. M.
Harding, J. A.
Harmon, J. A.
Harris, W. P.
Harvey, R.
Hayes, W. T.
Hayhurst, R.
Heanley, C. M.
Henry, I. G.
Hewitt, H. G.
Hieatt, R.
Hoath, A. C.
Hoefft, H. U.
Holt, D. I.
Hosker, J.
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Howell, O. B.
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Hurford, J. H.
Hyde, C. J.
Jefferys, J. G.
Jeffery, A. J.
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Jobson, R. W.
Johnson, A. R.
Jones, N. H.
Johnson, P.
Kennedy, W. H.
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Lane, F. K.
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Mills, H. T.
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Nelson, R. A.
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Tobutt, D.
Toon, D. A. J.
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Vuille, B. A.
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Yates, F. L.
Young, T. G.
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